THE FIELD PRACTICE OF RAILWAY LOCATION

BY

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Late Chief of Locating Party on Gould's Southwestern Systems of Railroads.

" *Why don't you compass it through?*"—B. S. WATHEN.

"*The direction of the drainage of your country is the framework on which you must hang your located line.*"

—D. W. WASHBURN.

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DEDICATION.

To the men of my locating parties, whose devotion to duty and steadfastness in hardship and danger has made me so much their debtor; to my superiors, who taught me and bore in patience my mistakes; and to Jay Gould of the Southwest System of Railways who paid for my practical education in railroad location; this book is dedicated by

THE AUTHOR.

THE FIELD PRACTICE

OF

RAILWAY LOCATION

BEAHAN

ERRATA

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95 2d paragraph, 2d word—read "Heliograph" instead of "Heliotrope."

102 4th line from bottom—read "Witness stake is driven one foot to the left of the hub" instead of "to the right."

178 Plate 5 in Example A, Rate of Grade should be 1.0 instead of 0.1. Make alteration in two places.

187 3d paragraph, 3d line, change 10° to 20°.

195 Line 18, change "beams" to "berms."

240 Under Computed Course, change "N39°58′E" to "N39°-59′E."

do. Under station 840+94.9 = PT, not PI.

241 Curve at "837" instead of "847."

246 In all References to Plates "A" and "B," reverse letters reading "B" for "A" and "A" for "B."

PREFACE.

The object of this book is to record the methods commonly used by American engineers in the west in the location of railroads built since the civil war.

In the thirty years just passed, more miles of railroad have been located in the United States than ever before in the history of any country within the working years of a man's lifetime. Before these locating engineers shall have all passed away the writer believes that a statement of their methods should be made. Their aid and their criticism is now available. There will never be in this country another generation of locating engineers who will have had so much practical experience in railroad location. This experience and experimental education has cost much. It is due to the capital which has paid this cost, that the knowledge as shown in the methods of these men be not buried with them; and it is due to these locating engineers that they be given credit for that development of method and skill in producing results which their study and genius have wrought. No other class of American engineers has faced so much danger, privation and exposure. No other class or number of engineers has received so little credit at the hands of the public for their work.

Who among these pioneers has ever written even a short paper on the subject, for the instruction of his fellow engineers? We probably have ten times the literature on rail section that we have on railroad location. Some years ago the writer tried to induce a locating engineer, who has, doubtless, more days of location work to his credit than any man living, to write a short but complete paper on the subject he had studied so long. He replied that he lacked the time; and "besides, could not talk as well as some of the members of the American Society of Civil Engineers could."

The life of a locating engineer while engaged is too busy for writing; when disengaged, his past isolation largely unfits him for contact with his fellows. The transitmen have given us a little of the methods of the older locating men, but by far the greater part of what little has been written on railroad location has been from the pens of men working in one locality and never engaged over a wide region for a term of years on location. It seems logical to study general methods as a means towards solving local problems of wide divergence.

The writer is not aware of any similar book on this subject. The book is primarily for chiefs of party, for engineers obliged to

make their first location, and for students. As much of economics, traffic, transportation, topography, geology and the locomotive is embraced in this book as those who use it will probably have time to study or consider. This is a book for the instruction of the inexperienced in this kind of field work, and it is made as plain and as consecutive in the statement of practical routine, as possible. No attempt has been made to exhaust the economic phases of the subject.

In so far as it is possible, each chapter contains all the information needed for that part of the work. The book is written from the standpoint of a chief of party, and its purpose is to aid other chiefs of party or those who may aspire to that position. A chief of party has a dual role, viz.: chief of party and locating engineer. The book recognizes this fact and contains much information for chiefs of party which is not strictly of an engineering nature.

Circumstances have given the writer the opportunity—long-looked for—of writing for the use of others what he has learned through experience and study.

The nomenclature used is the usual one in field work; and where the term is more colloquial than scientific, it is placed within quotation marks. These terms are familiar to old field men, and are here introduced so that others may learn them when their use aids the understanding. The nomenclature of Weisbach's Mechanics is followed, and the significance of the letters used is given at least once in each chapter where they occur.

The economic units and the principles established by the late A. M. Wellington in his valuable book, "The Economic Theory of Location of Railways," are here used, and referred to by chapter or section in each case. Had the book just mentioned never been written, this present volume would be of a very different nature and probably much less useful. It is now a book on practice based on established theory. Mr. Wellington was studious and brave enough to venture first into the untrodden field of the economics of railroad location. All honor to him for his conscientious labor. His work has now passed through "the winnowing mill of time" quite unscathed. His patience in research, marshalling of data in tireless tabulation, and his breadth of judgment have given us a veritable library on railroad location and its allied topics. It is still, in the writer's opinion, an authority in railroading.

In the present work, the order in which the chapters (as well as the topics within each chapter) are arranged, is aimed to be that in which these matters naturally face one who is taking up the problem of the location of a line of railroad.

The writer believes that no locating engineer has ever been successful in a marked degree who has not been *in reality* a good topographer. A chapter has been devoted entirely to this subject. It was written by a geologist of extensive field experience who made topographic maps of the country he surveyed geologically. Much emphasis has been placed on reconnaissance work.

The chapter on the locomotive contains only those elementary principles of locomotive design, proportion and capacity which a locating engineer must know before he can intelligently "break grade," "cut trains in two" or use "pushers" at divisional points, or special hills, e. g.; if the trains cannot be hauled farther with the standard "Mogul," how much must he "break" and increase the gradient in order to use *economically* the standard "Consolidation" or "Hog," which is the road's next heaviest locomotive? If he uses a certain pusher common to his road how much must he break his grade to tax the road and pusher engine to their economic working load? These are very practical questions. Here the civil engineer must enter slightly into the field of mechanical engineering.

While the locating engineer has need of this knowledge just outside of civil engineering proper, he also needs experience in other directions in railroad engineering. The writer insists that, in his opinion, no locating engineer can do his best work until he has also had considerable experience in construction and in maintenance of way. In short, he must be a *railroad engineer* before he can be at his best as a locating engineer of railroads. Railroad companies suffer much by having civil engineers who, while excellent in their profession, are not at all railroad men.

The chapter on the relations of topography and geology was entirely written by Prof. J. C. Branner of Stanford University, California. His long experience in field work in geology both in South America and in the United States is too well known to need mention here. That topography has geology for a bas: was a principle noticed by him in his work.

The author has made use of valuable personal letters received by him from the late Mr. Frank Davis, an honored graduate of the University of Michigan and an experienced locating engineer in mountain work. His death near Guayaquil, Ecuador, has deprived this book of a chapter he would have written which was to pertain to Mr. Davis' own methods in mountain location work. He was one of our most capable locating engineers, and his death is a loss to our country.

Mr. Wm. Hood, Chief Engineer Southern Pacific Ry. Co., has placed the author under many obligations for a full explanation of his methods used in his work, extending as it does over the greater part of the mileage of that g eat system. Many of his methods are embodied in the following pages. Not a few had been copied from him by the author in his own field work some years ago. Mr. Hood fully intended to write a chapter for this volume, but his professional duties were too exacting to permit his giving the time necessary.

Mr. B. S. Wathen, Chief Engineer, Texas & Pacific Ry., had also hoped to be able to contribute a chapter. But his time has proven to be too much engaged. Mr. Wathen was the writer's first teacher in railway location practice. Much of Mr. Wathen's excellent plains methods will be found underlying this method here

outlined, viz.: "Heed the direction; observe closely the drainage; keep well out and ahead with reconnaisance, and always take good care of your party."

The principles of railroad practice to be found in this book are undoubtedly those of the late D. W. Washburn, Chief Engineer of construction work on Gould's Southwest System in Texas, who gave the writer his earliest and best railroad training.

Winona, Minn., June 1, 1903.

CONTENTS.

The Field Practice of Railway Location.

CHAPTER I.

The Character of the Road.

It is the object of this chapter to introduce the subject of the field practice of railroad location by stating briefly such matters as must form the basis and nature of the demand for a railroad. A railroad rests on earnings; earnings rest on traffic; and traffic rests upon production and population. The product is largely of the soil, the forest or the mine, and can be seen, located and measured. Railroad science should do this. The product can only give traffic when population gives consumers for that product. This consumption may be direct, as of fruits, dairy products, etc.; or it may be indirect, as of iron or timber. The demand for product can also be seen, located and measured. Railroad science must do this. To locate the product and consumer is practically, but not technically, railroad location. The product and the consumption being located and measured, it is necessary to find how and where a railroad can bring that product and that consumption the nearest together in time and practical cost. This is a problem of railroad location, pure and simple. In this chapter the question of railroad location will be discussed in the broader sense, while all subsequent chapters will apply to the technical questions.

A railroad may be defined as an artificial avenue of commerce, designed and built to earn for its owners its cost of operation and maintenance plus a certain per cent. upon its cost of organization, construction and equipment. It is in its nature mutually beneficial to owner and to patron, for it lessens cost of transportation, or it could not replace the canal and the turnpike. It has made what were luxuries once, necessities now, by largely reducing freight rates. It has made us travel more, by increasing the purchasing price of each dollar we pay for passenger transportation. A railroad is less trammeled than a natural commercial route like a river, or the artificial route known as a canal, for such routes depend upon water acting under gravity in a manner to aid commerce. A railroad is therefore a freer commercial factor than its competing systems of transportation, and can do a people more good, because it is more elastic in adapting itself to a nation's needs.

Grave questions are complicated with present railroad matters throughout the world. Railroads are too young to be understood financially or sociologically. But that they have accomplished much, and have given great impetus to the world's growth in the last generation is very evident. Once popular in America, like immigration, they are now very unpopular. Railroads have made

lands valuable which, without railroads, would be valueless, and they have much reduced the value of other lands. Railroads have built cities, and have made some cities overshadowing in population and in wealth. They have dwarfed other cities, killed thousands of villages and robbed former agricultural districts of their prosperity. For the time being, we lose sight of the great good railroads have done. We now see the evils they have done. We do not see that development in one direction must needs have been attended by at least temporary destruction in another direction. A study of railroads and a better knowledge of their real character will probably enable us to use them without their abusing us. Virtue cannot be legislated into a railroad nor into a man. The growth of cities at the present rate, is not desirable. Can legislation stop it? Railroad freight rates are often too low and, still more often, not uniform. Can the act of a legislature check this tendency? The entire question of the nature and spirit of a railroad is intimately associated with railroad location. If one does not know or care what a railroad really is, he will blunder in locating that railroad. He may be clever, but he cannot be sound, and will therefore fail.

By the *character* of the road is meant the special *purpose* of the road, and the *class* of the road in design and excellence. By the *purpose* of the road is understood that use to which the road is to be put by its owners; whether as a new main line; as an extension of an existing main line; as a cut-off for some existing line; or as a branch road. By the *class* of the road is meant those qualities in the design of location and construction which should be the direct expression of the kind, direction and volume of the traffic. In one sense, the character of the road is almost another expression for the cost of the road, for traffic justifies cost. In design a road may be planned to represent much or little capital. It may seek to annihilate distance, both horizontal and vertical, as did the South Pennsylvania Railroad which sought by heavy work and tunnels to shorten distance and decrease rise and fall as compared with the Pennsylvania railroad. Or, a railroad may be designed to represent but little capital.[1] It may be said that the class of the road is largely affected by the amount of money available for its construction.

We have said that a railroad is a most flexible avenue of commerce. We have intimated that it can traverse country which a

[1]The Auburn Branch (known as the "Old Road") of the New York Central and Hudson River Railroad was built by local companies and for local use. In Ontario County, New York, the line runs to nearly all points of the compass within that county. The West Shore Railroad forms a contrast to this and was so pronounced a through-line that it left the city of Rochester a small distance off its route. Each road mentioned differs in design. As an illustration of railroad construction and location for present profit rather than for future gains, it may be cited that the instruction of a pseudo-president of a railroad to his locating engineer in Kansas in 1886, were these: "Follow the grass roots for grade line, and the local subsidies for alinement."

canal can not because gravity and water must be made to work together in artificial water-ways. This gives railroads a far broader field of usefulness; they are more readily duplicated and therefore more dangerous. There is another attribute of a railroad—the quality of being everlasting. Practically, it cannot die. Bankrupt, it is still more active. Dead, financially, it is even more alive commercially—for mischief. The ideal location for a factory is at the intersection of several good railroads, and of one railroad in the hands of a receiver. The bankrupt road is a mighty weapon in the hands of that manufacturer with which to beat down rates of the solvent, healthy roads. Chartered, the insolvent road cannot go out of business, as we now read our laws. And, though the railroad be still-born during construction, it exists just the same—of no profit to its owners, and a menace to the real business interests of the community.

Railroad managers are today very much embarrassed by roads once useful, but now dead through bad design—the hulks of commerce; by roads never built where traffic could handily use them, and by roads really never built at all, but merely thrown together as a pretext for construction profits. The superfluous railroads must be taken into account in the location of new lines, and must be rated as a very troublesome question for the traffic manager of the new line. They are the relict of the espousal of the transportation problem by the hustings of our earlier years.

The student of railroad science needs to discriminate between roads built through stupidity or short sighted speculation, and those built through that larger speculation which in its breadth and scope has been the life of our nation. To quote from a well-known authority:[1] "Speculation is a necessity of modern life. Modern business involves large risks; someone must take them. The important thing is that the risks should be taken by men with judgment to foresee the probable effects, and property to stand the possible strains; and that men who lack the judgment and the property should not take the risks." This larger speculation of men of means and daring foresight has given the greater impetus, first to canals and then to railroads. Condemned by public opinion it still ministers to the general good.[2] The gains of these men are noticed and forever dwelt upon, grudgingly; while their losses, often as stupendous, are lightly seen and soon forgotten.

From timidity to compete with canals save where the product required dispatch or was liable to decay, the railroads, through competition mainly among themselves, have so reduced cost of op-

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[1]Railroad Transportation, by A. T. Hadley, p. 49.

[2]"The construction of the Erie Canal (1817 to 1825) reduced transportation charges to little over *one-tenth* their former figures." See Railroad Transporation by A. T. Hadley, p. 31. The average reduction in the United States in passenger rates on railroads in 25 years (1871 to 1896) was 23%. The average reduction in railroad freight rates in 30 years (1867 to 1897) was 58%. See Railway Economics by H. T. Newcomb, p. 27, *et. seq.*

eration that they have forced the canals to such low freight rates that canals can no longer pay their operating expenses.[1] Governor Clinton embarked the State of New York in that large speculative building of the Erie Canal. The canal was then very remunerative. It is now a problem. The Empire State was strong enough to take the risk.

Jay Gould built or bought the roads of his Southwest System. Some proved profitable, some scarcely so at the time. He was strong enough financially to assume the risk. Probably weaker men would have been unable to do so. This larger speculation requires large funds and no little bravery. And for such speculation rich men and rich commonwealths are a necessity.

The laws which regulate the direction and general location of a railroad are both commercial and topographical. Commercial laws demand that railroads exist and operate between the producer and the consumer. The traffic will flow either or both ways over the road, usually with the balance of traffic earnings largely in favor of one direction. That this balance of traffic is not exact, but an overplus in one direction, adds much to the cost of operation and maintenance, is a source of stumbling to novices in railroad matters, and of late years has helped demoralize rates through *back loading*. For, it is economy to load an empty car, having no legitimate traffic, with unnatural traffic at any rate which a little more than covers the difference in cost between hauling the loaded car and hauling the empty car. Oregon shingles thus reach Indiana, passing Michigan; and Pennsylvania coal reaches Minnesota, passing Illinois. This principle creates artificial flow of traffic.

It is not true that producer and consumer always retain that relation to each other. Obviously, when the producer becomes, for the time being, the consumer, the balance of traffic tends to be reversed in direction. Nevertheless, it is the rule that the traffic earnings and tonnage are greatest from the crude product toward the mill and towards center of population, and that while the rate per ton mile is less on crude products, the increase in rate on finished product, machinery and luxuries does not make up for loss in tonnage. That is to say, the freight on a farmer's produce is greater in dollars and cents than the freight on his clothing, groceries, machinery, coal and other supplies. On western roads from the best farming regions to Chicago, for example, this balance of traffic is very largely in favor of eastbound business and the westbound tonnage is far below the eastbound tonnage. Low rates for back loading lessen this balance and give the farmer supplies from unnaturally great distances, or induce him to use what he otherwise would not think of using. Even on the Pennsylvania

[1] Dorsey in "English and American Railroads Compared" shows (see p. 74) that the New York Central Railroad from 1870 to 1883, inclusive, has decreased its average freight charges one-half per ton-mile. He states that the Penna. R R. within the then (1885) last twenty years had reduced its average freight charges *two-thirds*.

R. R., one of our very best eastern trunk lines and located between termini having enormous traffic, this tendency to unbalanced traffic is marked.[1] The average freight mileage for all their divisions has shown for a year that 74.5% is eastbound and 25.5% westbound. This means that, while all eastbound cars may be loaded, for every loaded car sent west two empty ones must accompany it.

TYPES OF SYSTEMS.

There seems to be something like a grand strategy for railroads in America. They start from certain points or regions, and they run in a certain general direction or on a certain general plan. This is a matter largely fixed by the laws of supply and demand, but modified by the topography or the "relief" of the region. In a general way, we have at least three different types of railroad systems:[2] The Parallel; the Outward Radiating; and the Inward Radiating. Let us remember that it is not true that every locality has its railroads outlined on any one of these three general plans. Nevertheless, there are lessons in this classification for the locating engineer and the railroad investor.

We have the Parallel system between the Northern Atlantic seaboard and the points to the westward in the Mississippi River Valley, notably Chicago and St. Louis. The list comprises the Pennsylvania, New York Central, Erie, and Baltimore & Ohio Railroads. Strictly speaking, the Lehigh Valley must be included in conjunction with the Grand Trunk. There are other roads that nearly or quite fulfill the conditions of roads paralleling these giant roads, all leading from the North Atlantic seaboard to the Mississippi River or the eastern side of its valley. These roads are parallel not from plan or choice but from the logic of events and natural laws. When one of these roads first reached from one terminus to the other, from the seaboard to the valley, it forced the other roads to extend by purchase or construction and to build parallel as the only way to secure as short a line. True, other roads exist in this region which are not parallel, but are they not less strong, less busy and less a factor in traffic? The greater part of the produce of the broad, rich valley of the Mississippi and the produce of the lands beyond, which must cross that valley on its way to market, naturally seek tide water along the lines of least resistance. The shortest line offers the least resistance, unless the gradients chance to make a line avoiding mountains the one of least resistance even though it be more circuitous. But, though the direction of all the lines is the same by the compulsion of through traffic, there is local traffic which is best obtained by each of these great trunk lines keeping far enough away from others to have its own *zone of local traffic*.

[1] See "English and American Railroads Compared," by Edward Bates Dorsey, page 124.

[2] Railroad Transportation, by A. T. Hadley, page 85 *et. seq.*

The Outward Radiating systems of railroads are now best exemplified west of Chicago as far as the Missouri River points and southwest from St. Louis. This radiation is outward from these two large cities as the spokes of wheels radiate from the hubs, and the lines point out towards producing districts. Probably the Parallel system east has made possible the Outward Radiating system just west of it. The position of Lake Michigan on the map shows added reason for a radiating system. From Chicago west and northwest spread out, among other important systems, the Chicago & Northwestern, Chicago, Milwaukee & St. Paul, Chicago, Burlington & Quincy, and Chicago, Rock Island & Pacific. From St. Louis west and southwest spread out the Missouri Pacific System and its allied lines and the St. Louis and San Francisco lines of the A., T. & S. F. System—a less perfect example than the northwestern lines. The Outward Radiating system is a collecting system for Chicago.

The Inward Radiating systems of railroads are most clearly seen in the southeastern States, south of the Ohio and Potomac and east of the Mississippi Rivers. Here the markets surround the producing region, and lie at all points of the compass on the seaboard or gulf coast or on the two navigable rivers. The topography, which has so located the markets, and the less restless character of the people tend to make permanent this system of inward radiating railroads. On the contrary, there seems nothing to hinder the western or northwestern roads from being in time converted from the Outward Radiating to the Parallel system. Chicago must needs then be a seaport, to some degree at least. St. Louis or some point farther down the Mississippi must be accessible for larger vessels, and railroads run parallel as far as Denver and the Rocky Mountains through competition for saving of distance. While speculation in this direction is hazardous, we may bear in mind that the Parallel system promises to grow while the Radiating systems, whether Onward or Inward, do not promise to replace the Parallel system. This fact gives added future value to savings in distances while locating lines.

This grand strategy in American railroads may be aided by topography or may be opposed by it. A road may run directly west from points on the Atlantic seaboard parallel to all direct routes from that seaboard to points of production west, and do so regardless of general topography. The Pennsylvania Railroad is a case in point. This road is much admired by civil engineers. Its corps of officers is exceptionally able, efficient and permanent, and their *esprit de corps* most excellent. Nevertheless, it is not clear that nature favored the route west from Philadelphia to Pittsburg. There seems to be no natural east and west thoroughfare through Pennsylvania. The 95-ft. per mile grade at Gallitzin just west of Altoona shows nature's barrier to the flow of traffic to be not inconsiderable. Skillful management has made a great road in spite of obstacles to location which were most serious. In passing,

it may be said that while the State of Pennsylvania seems to offer no east and west routes, it has but four north and south ones, while its northeast and southwest routes are numerous.[1] Of this latter fact, the trend of the county boundary lines gives apparent proof. A valley comprises a county's breadth and the sharp mountain ridges are the county lines, separating the State into civic communities.

Eastern roads were begun as local roads and without design. We differ from the French people in this respect. They designed first, then built. The Baltimore & Ohio Railroad, the first American railroad, fared even worse than the Pennsylvania Railroad for its maximum gradient reaches what may be termed the congressional limit (prescribed for the aided Pacific Railways) of 2.20 ft. per 100 ft., or 116.16 ft. per mile. Each of these two roads just mentioned was local to its state, city or community, and local pride and enterprise overcame the mountain barriers of nature, as it will invariably do in America.

Contrast these cases of topography opposed to grand strategy, as in the Penna. R. R., with the case of topography aiding that strategy (though imperfectly) as in the New York Central R. R.

The Appalachian chain of mountains is quite unbroken in the state of Pennsylvania. The Hudson River breaks through that chain at the Palisades in the state of New York.

This means practically no gradient through the eastern coast range for the N. Y. C. R. R. as against 95 ft. to the mile for the Penna. R. R. Besides this there is a river, the Mohawk, emptying into the Hudson River at Albany, and, what is very important, the geologic out-crop there crosses the State from east to west, insuring easy gradients. At Buffalo the great lakes are reached and insure low gradients into Chicago and other lake ports. Topography aids the New York Central enormously from New York City to Chicago. But it does so at the loss of distance, for Albany is 150 miles north of New York City. Nevertheless, it is probable that in this case the base-and-perpendicular route of the New York Central on easy grades between New York City and Chicago offers less resistance to traffic than the hypothenuse route of the Penna. R. R. on quite heavy grades, excellently operated, between the same cities.[2] This case shows us that while directness of route is a great desideratum, topography and geology are modifying forces.

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[1]These four north and south routes are along the rivers whose general course is south; viz.—the Delaware, Lehigh, Schuylkill and Susquehanna Rivers. Taken in their order from east to west, they now provide quite feasible routes for the Belvidere Division of the Penna. R. R., the Lehigh Valley R. R., the Schuylkill Divisions of both the Pennsylvania and Philadelphia & Reading railroads, and the Northern Central Railway.

[2]The distance from Chicago to New York City via the Penna. R. R. is 912 miles, while via the N. Y. C. R. R. and its connections the distance is 980 miles.

The investor and the locating engineer may, with profit, go back a little further in history and note that the most powerful of the Indian confederations once held the country now traversed by the New York Central R. R. They then levied tribute on commerce and travel just as that railroad does to-day. The Six Nations (or Iroquois) held that natural avenue of commerce and compelled other Indians to pay for passing through their country, because it was cheaper to pay toll than to go around.

These Six Nations were not separated by natural barriers—such as rivers or mountain ranges—as in Pennsylvania. The geologic out-crop and Mohawk River gave them ease of inter-communication and made their confederation possible. Located in a natural avenue of commerce they levied tribute. Profit from it made them strong, intercourse made them farseeing. The Iroquois never numbered over 5,000 warriors, but they were dreaded and feared by many tribes far more powerful. Their "Long House" had its eastern door at the Hudson River where the Mohawks, one of the Six Nations, stood guard, while its western door was west of the Genesee River and there the Senecas, the most powerful of the six tribes, kept watch. Do not the causes which made the Iroquois powerful make New York the "Empire State?" Is it true that where Nature unaided compelled traffic to flow we can now most economically conduct traffic? "The possibilities of power are both in the topography of a country and the characteristics of her inhabitants."[1]

We can most easily be wise in our own generation by studiously trying to stand upon the shoulders of our wisest predecessors as pointed out by history. Was it not wise for the Atchison, Topeka & Santa Fe Railway to follow closely the Old Sante Fe Trail as it finally started southwest?[2] It was found by Alvar Nunez Cabeca de Vaca some three and a half centuries before. None know when it was located, and it rather grew, no doubt, with the needs of the Indians or Aztecs. Not a few of us know by experience that its route had the lowest summits and its stream crossings were most practicable.

Nor is even a buffalo trail from the high plains to the head waters of the streams to be despised as a guide to the locating engineer in climbing out of the valley. How they ignored small obstacles and cut a roadway through them! How straight the trails are in general trend, and how seldom are their turns abrupt! Later years have shown us that our first Pacific Railroad crosses the Rocky Mountains too far south, perhaps, for easy gradients. The Great Northern Railway, last built, has the lowest Rocky Mountain summit and gradients. There is a flattening out to the north of the mountain ranges. And it would now appear that that country will produce more for local traffic, and has greater promise

[1]Hon. Chauncey M. Depew in a speech at Albany, New York, on Jan. 6, 1897.

[2]See "The Old Santa Fe Trail," by Col. Henry Inman

for great communities and states in the future, than has the region through which the Union and Central Pacific passes. Is it not true that the Indian tribes of the North (the Sioux, Crows, etc.) were more powerful factors in Indian times than their southern neighbors? All of this suggests that while railroads do much towards making commercial history they are at the same time a part of that commercial history. Engineers need to be cognizant of these facts.

EFFECT OF MONOPOLY.

These things just mentioned are Nature's monopolies, for mountains and adverse drainage are barriers to competing routes. Whatever destroys competition aids the growth and makes possible the life of monopoly. Legislation cannot flatten the grades of the Pennsylvania just west of Altoona. Beside these natural barriers which check or even tend to annihilate competition there are commercial or industrial barriers. These are also difficult for legislation to correct.

We live in an age of industrial monopoly. "An industrial monopoly is where the business interests of the parties concerned make competition practically impossible, even when there is neither law nor natural obstacle to hinder it."[1] We have outgrown free competition. Cheaper transportation has been long since possible through combination. Some who are little versed in these matters do not see that it is all a matter of natural growth. Some are injured; more, helped. Wrong is done that good in far greater measure may ensue. We should not be surprised, for Geo. Stephenson, who may be called the father of railroads, said on this point "Where combination is possible, competition is impossible." Yet we permit our legislators to pass laws against combination of railroads and in favor of chartering or even subsidizing "wild-cat" lines. Railroad combination is not an unmixed blessing, but it does "give the greatest good to the greatest number." A railroad is our servant and not a robber within our gates. It must not be throttled nor allowed to commit suicide. *A pool* is nothing more than railroad life insurance. And it is worth most to the best lines, just as life insurance is worth most to the best individuals. A road or a man with no "expectation of life" shuns a pool or a "policy." Legislation against pools keeps alive lines that ought to die, and nurses into considerable growth lines not needed or built solely to levy blackmail. Regulating commerce by legislation is not a simple matter.

Those who have studied it most are least sanguine about speedy, simple remedies. Out of 40,000 railroad stations in the United States but 4,000 are competitive, that is, have more than one railroad. Among this last number combination rather than competition is the rule. Combination tends to develop certain favored

[1]Railroad Transportation, by A. T. Hadley, page 64.

sections, selected largely by chance, at the expense of other sections. As a rule there is seldom malice in the case. When there is, it is not malice of the railroad company, but malice of some officer of the road without the knowledge of the highest officers and with no benefit to the company. Combination especially tends to over-develop cities. This, too, is quite unintentional, and arises from laws, industrial and civic, entirely outside the knowledge or intent of railroad administration.

Before passing from the industrial phase of our subject, we must speak of the principle of charging as a traffic rate for service "what the traffic will bear." The idea has for its object the increase of revenue. As a rule it increases volume of traffic and lessens the average rate per ton-mile. Undoubtedly there have been unwise railroad managers who have raised rates, and by so doing destroyed property, stopped factories and lessened volumes of traffic. The natural result tends to punish such acts by lessening the revenue. The traffic will not often bear such treatment. It is quite clear that the principle lowers cost per ton-mile, *as an average*, and its baleful effects are not by any means as self-evident as we have been led to believe. "Back loading" rates is one form of this principle.

Having considered in outline the conditions which surround a railroad, we will endeavor to show briefly how a railroad originates, and define the common terms which recur often in studying them.

THE CHARTER.

The earliest requisite for the existence of a railroad company is a charter. In European countries and in Spanish America charters are from the highest governing body, e. g., Parliament, etc. In the United States a charter may be, and in the past has been, for Pacific Railroads, from Congress. But the trend of our institutions, and the practical procedure to-day, is to seek a charter from the State government for the line in that State. If the road is to traverse several States a charter is needed for each of those States.

Two attitudes towards charters for railroads exist; the one is to scrutinize and require cause; the other to facilitate and ask no questions. To scrutinize is the European, the Spanish-American, and to us, the foreign, method. This attitude of the government requires that the railroad company must submit to searching inquiries as to its financial strength and real purpose, and frequently be asked to show why it believes there will be traffic to justify construction. It must file maps, profiles and estimates of great accuracy. Is the road needed? Can this company furnish the money to build it? Will it pay a reasonable income upon the capital invested? These are the queries made. As has been said, this attitude is foreign to Americans, but it is not unprofitable for railroad men in the United States to consider it. The policy of

scrutiny, as we may call it, has its drawbacks. It is slow. It breeds a lobby and, like a mosquito, a lobby grows in a night. For at the very inception of railroads in 1826 in England, the Liverpool & Manchester Railway expended $350,000 to secure a charter from Parliament, and even then "it needed a politician like Huskisson to carry the charter through."[1]

From 1871 to 1882 there was expended in Great Britain in promoting or opposing bills before Parliament for railway, gas and water companies a total of $23,324,370 for the eleven years or an average of $2,120,397 per year. How much of this was for railroad lobbying we can only surmise. Do we want such a system, where "nearly all the prominent engineers have their offices in Westminster, near the houses of Parliament?[2] On the other hand, we must see at once that this attitude of scrutiny stops wildcat, irresponsible lines. That is no mean benefit. It might make impossible such lines as the West Shore and such projects as the South Penna. R. R. It increases the security of capital now invested in railroads, and gives existing corporations time to fight blackmailing enterprises. It might even have avoided the necessity of pools to-day.

The other attitude of governments towards railroad charters is the one peculiar to the United States which *facilitates* rather than *scrutinizes.* It is based upon the principle that a railroad is a state and a national good, and that the more railroads we have the better. Usually no difficulties are put in the way, and seldom are any questions asked. In Kansas in 1886 *any* person, known or unknown, could get a charter to build *any* amount of railroad *anywhere* in the State by asking for a charter and paying one dollar. Will conservative capital invest in railroads where such laws exist? Is speculative investment in the road beneficial to the citizens and the interests of the State? Will not this principle build roads for which there is no real use now, and never will be? Are these drawbacks to our system of granting charters sufficient to make us wish to amend our system? The benefits of our plan are evident. It gives free rein to enterprise and lets a strong young giant in natural resources use its surplus energy. It stimulates youth, whether in the man or in the nation. It is democratic, not aristocratic. It places effort before name. It probably increases rapidity and breadth of development in the broadest sense, at the expense of increased cost. It would seem to be attack by assault rather than by strategy.

A railroad charter is virtually articles of incorporation, and makes the individuals petitioning for the charter a corporation in contradistinction to a firm. It lessens their liability, limiting it usually to their stock invested, and releasing their other or in-

[1]Railroad Transportation, by A. T. Hadley, page 164.

[2]English and American Railroads Compared, by Edward Bates Dorsey, page 4.

dividual property from liability. The charter has a second inherent right, that of entering upon land for purposes of survey and later acquiring the land for railroad purposes by condemnation. This is given by right of "eminent domain" of the state, and is essential to artificial avenues of commerce—railroads, canals, etc. Each State prescribes its own way of issuing railroad charters. Usually not less than five persons must sign the petition, and it is sent to the Secretary of that State where the line is proposed to be built. A moderate or nominal fee must accompany the petition. The persons on receipt of the charter comprise the railroad company. They open a stock subscription book and have the right to accept subscriptions for stock. When all or a certain per cent. of the stock is subscribed for, the next step can be taken. It is often permissible to hold a minority of stock in the treasury, for the time being. This need not be even subscribed for, as yet. The stockholders elect certain of their numbers directors, usually for one, two and three years. These directors choose from the members of the directory, the president, secretary, treasurer, etc.—usually for one year. The petition asks, and the charter always grants, the number of directors desired and specifies the titles of the officers to be elected by the board of directors with the term of office of each. All other officers needed in the business of the road are employed—not elected—and hold office at the discretion of their respective superiors. Officers elected by the board of directors must be re-elected each term if they continue in service, and cannot be dismissed in the interval save by the board at a meeting.

Certain terms recur constantly and arise from the charter—all as asked for in the petition. The name of the company is so fixed. The amount of its capital stock is fixed by charter. This "stock" is synonymous with the English "shares" and may be stipulated in the charter, thus "the capital stock is fixed at $1,000,000, consisting of 10,000 shares having a par value of $100 each." The company exists by reason of a charter and because it has the right to organize and issue certificates of stock on receipt of the price. The stockholders are the railroad company and each share has one vote. This is the normal status.[1]

[1]Certain financial terms need explanation here. They arise, usually, at this period of the company's life or are connected with initial acts of the company:

(1) *A Fixed Charge* is interest on bonds, rentals or such obligations as are to be paid at a certain lapse of time regardless of other conditions.

(2) *Gross Earnings* comprise, what the term signifies, all the earnings of the road with none of the expenses deducted.

(3) *Operating Expenses* exclude fixed charges, but comprise all other expenses. Operating expenses are of three kinds—Maintenance, Train (or movement) expenses, and Administration (Station, Terminal, General Expense and Taxes).

(4) *The Net Earnings* usually mean Gross Earnings minus operating expenses.

(5) *Surplus* is the amount remaining after deducting the total Operating Expenses plus the total Fixed Charges from the total Gross Earnings.

The charter usually grants, at the request of the original petition, the right to issue bonds. A bond is a "mortgage," or essentially a "deed of trust," according to the terms used in a State. It usually carries with it the right to summary foreclosure or even summary possession without foreclosure whenever the interest on any bond is not paid when due. The charter stipulates the total amount of the bonds, the denomination, rate of interest and date of payment of interest, and the date of maturity of the bond, at which time the (par) value of the bond must be paid. For example, first mortgage bonds to the amount of $5,000,000 may be issued for sums of $1,000 each, to be paid in the year 1910 and bear 5% interest per annum to be paid annually on the 15th day of July of each year at the office of —— Co. in the city of ——. The owners of these bonds comprise a class of investors—bondholders—having as yet no voice in the management of the company. When the interest on the bonds is not met when due the bondholders may petition the court and ask that a receiver be appointed for the railroad company. The judge of that court may appoint one if he believes the company insolvent. This receiver is an officer of the court. The road is then in the hands of the court and cannot be sued. The board of directors and the officers of the company elected by them have no voice in the management. The road ceases to have fixed

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From the Surplus only can dividends on stock properly be derived or any sum set aside for construction or for future needs.

(6) *A Sinking Fund* is an amount taken from a Surplus and set aside to meet future liabilities. It is like cash deposited in a bank by an individual, kept for emergencies.

(7) *Stock* is the capital of the company authorized by its charter as recorded on the books of the company. Stock is divided into shares of an equal par value of usually $100.

Preferred Stock is usually issued later in a Company's history on authority and takes preference over the former Stock—which now becomes Common Stock—in priority of right to dividends.

A road may pay dividends on its Preferred Stock and not on its Common Stock.

(8) *A Dividend* is a certain percentage of the par value of the stock paid as a profit on the capital so invested.

(9) *An Assessment* is a certain percentage of the par value of the stock to be paid as a tax on the capital so invested.

(10) *A Bond* is similar to any other bond in its nature, and is a first claim upon the property. It is by nature a mortgage. *Interest on Bonds* is the stipulated rate of interest per annum which the company is compelled to pay the bondholders. It is a fixed charge on the property.

(11) *A Debenture* is the British term synonymous with the American *Bond.*

(12) *Consols* signify consolidated indebtedness, and are usually bonds of several classes of an old company consolidated together at the time of a reorganization to avoid so many classes of bonds. The term is most used—probably was first used—in England.

(13) *Junior Bonds* are those having some other issue of bonds which take precedence in interest payments by reason of priority of issue or claim. They are not first mortgage bonds.

charges, and ceases to have responsibility. It pays no interest on stock. It pays interest on bonds if its earnings permit. Legally and commercially it is a free lance. Beyond a reasonable doubt our laws pertaining to receiverships in general have a pernicious effect. Designed originally to save a railroad from destruction piecemeal, they exist as an aid to the large investor in active control to use a receivership to crush the small investor. They often aid the investor who is an enemy of the company to menace its financial standing and cause heavy losses to bona fide investors whose interests are wrapped up with the interest of the company. The receiver is often either the friend of the large investor or the friend of the judge. His fitness is often of secondary consideration, and his efficiency as a railroad man does not need to be shown in order to insure his appointment. At this time men of a better class with more knowledge of railroad affairs are being appointed.

Theoretically a share of railroad stock is supposed to cost the original stockholders par at the time of the organization. This is the custom in corporations other than railroads. Practically a share of railroad stock may cost as much less than par as the organizers of the company may desire. Sometimes a share of stock is given away to each person who buys one bond, or one share of stock for every two bonds, etc. While some stock is being given away, other stock may be being paid for. This is speculative investment and not construction investment.

Theoretically a railroad bond is usually supposed to be issued after the capital has all been subscribed for and all paid in and found to be insufficient. The bonds are issued as a mortgage on what has already been built. Usually the bonds are expected to sell at par, and should do so always, if the capital stock has all been wisely used to create property in the form of a railroad. Practically a bond may be sold by a company to its members at any price, or be a gift to them. Or, the bonds may represent the *only* capital invested.[1]

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[1]Certain Stock Exchange terms are common in Wall Street transactions and are not intelligible elsewhere.

A *Bull* on stock is one who wishes that stock to rise in price. The term is supposed to be taken from a bull's method of attack—"tossing *up*."

A *Bear* on stock is one who wishes that stock to come down in price. The term presumably arises from the fact that the bear attacks by "pulling *down*."

A *Straddle* is the attempt to be both a Bull and a Bear on the same stock at the same time—a term little used.

A *Put* is a contract where a strong operator financially obligates himself that for a certain length of time a certain amount of a certain stock may be *put* to him at a certain price. It is an insurance against loss through lower prices.

A *Call* is a contract—the reverse of a put—the stock being held or must be obtained by the strong financial party on *call* as per contract. It insures against loss through higher prices.

A *Margin* is a certain percentage paid on stock usually by weak financial operators, or non-investors, and for purposes of large speculation on small

A road earning less than its operating expenses and fixed charges usually seeks to have its fixed charges reduced through receivership and a reorganization, thus inducing the bondholders to consent to a lower rate of interest on bonds or to surrender a part of their bonds to the company without pay. A road earning more than its operating expenses, fixed charges and a good rate of interest on its stock usually avoids apparent over prosperity by a stock dividend or by "watering the stock." A stock dividend consists in giving to each stockholder having, say, ten shares of stock one new share of stock without pay. Or, under the same circumstances, feeling assured that the road will pay, say, 8% on $5,000,000 more stock, the company issues that amount of new stock and sells it. This is termed watering stock. But new stock is not necessarily watered stock. Suppose, for example, a road expends a large surplus for new, extra heavy rails. It is right to distribute new stock gratis and pro rata to its stock holders in lieu of that surplus.

NEW MAIN LINES.

What class of road is it proposed to locate and build? The line may be the parent trunk, or an extension of it, or a *cut-off* for it, or a branch of a certain kind. It may be cheap or costly in construction. If the line to be located is the first line of a contemplated system we have the question of a New Main Line. This is the broad general case of railroad location. We then have the fewest facts that are reliable, and often assumption forms no small part of our basis for operations. What may be fairly considered as the last new main line of considerable length built in this country (1890-1893) was the Pacific Extension of the Great Northern Railroad from Great Falls (or some point back of it on the line) to the Pacific Ocean.[1]

capital. It is a first payment on the installment plan when later payments are not contemplated. It is much the same as an option on stock at a certain price. If the stock falls to where the margin paid will scarcely cover the depreciation the broker has the right to sell the stock. The margin is then said to be "wiped out."

A *Corner* is a combination on stock to control the price by controlling large quantities of the stock secretly. Others cannot buy to deliver stock as contracted for, except of the "corner," which thus dictates prices to those "short." One is "short" on stock when he has sold more than he has. To be "long" is the reverse term.

Watered Stock is a term originating through the late Daniel Drew, of Wall Street fame. He said that issuing new and added stock on old companies not based on *new* property, although based on new earning power, was like a farmer he (Drew) heard of when a boy, who "sold his fat steers by the pound, salted them well and then let them drink all the water they could just before delivering and weighing them." Popularly, watered stock is *fiat* property; practically, it may represent increased earning power through wise combination or more efficient management.

[1]See Journal of the Association of Engineering Societies for August, 1893, for paper by E. H. Beckler, C. E., before the Montana Society of Civil Engineers.

The Chief Engineer of the work, Mr. E. H. Beckler, states that "Among the problems to be considered are the following:

1. Several routes between different termini.
2. Relative distance by various routes.
3. Probable grades by various routes, and helper grades.
4. Elevations and depressions, i. e., Rise and Fall.
5. General and specific alinement.
6. Character of country for resources for traffic.
7. Character of country for climatic conditions.
8. Convenience in operation as regards other lines of the same system.
9. Present occupation of the territory by other lines.
10. Comparative cost of construction and renewals of structures."

Some of these matters for consideration can be determined without actual survey from examination of existing maps of the country and a knowledge of the resources and other conditions. It is evident that some points in comparison are not capable of expression in terms of a money value. Values should be given as far as possible. Evidently the work was planned before execution of surveys. As this is not a perfect type of a new main line the 8th point to be considered does not apply to the general case. In Europe the Ordnance Surveys or other governmental surveys of extended areas enable one to determine closely the route of the new line prior to any railroad surveys.

TRAFFIC.

Traffic is the first consideration. For this new main line, how much traffic is there in sight? If there be canal or river traffic on the proposed line how much is there, and what part of it can you surely divert to the railroad. If there be another railroad, say 50 miles away and parallel, how much local business has it in that region, and what part of it comes from that side of the existing line which will lie between you? We should ordinarily get half of the traffic in that 50 mile zone. Will there be a difference in the facilities in the two lines to increase or lessen that 50% division of traffic? Traffic *in sight* is most easily measured, and must first be taken into account.

Secondly, how much traffic can be surely and speedily developed? This is a more difficult question than the first. If the traffic must come from mines, great care is needed before capital is insured against loss. Is the mineral really there? In what quantity? What will it cost f. o. b. cars?[1] Where is the market, and to what extent is it local traffic, or other traffic? What selling price will it command in that market against all present

[1] The term "cost f. o. b. cars" is a phrase in railroad parlance meaning the cost "free on board cars," and is the actual cost of the product at the time it is ready to be moved by the railroad company.

competitors? Do other competitors promise to be in the field? What will it actually cost to haul that traffic? Now, the difference between the selling price of the product and the sum of the cost of production and cost of transporting it to market leaves a balance which the mine and the railroad must divide between them as a profit. Is there enough for both? Finally, are we sure of a fair division? If the traffic is from a forest, the timber is in sight, quantity and quality. If the traffic is farm produce, the soil, climate, rainfall and, last but not least, the class of inhabitants are the factors of the problem.

The better the class of inhabitants the more crops they will raise, and unquestionably, the better their class the more they will consume. Civilization increases traffic. The higher we rise in its scale the greater our needs in living and the more we travel on railroads. Lower rates induce traffic and the habit of using railroads is growing in the United States.[1] The inhabitants produce traffic—freight as well as passenger traffic. This is general traffic. It is per capita traffic. It is a function not only of the number of inhabitants but of their quality. The wants of an Englishman in England are more than those of a Jamaica Negro in his native tropical island. Each average inhabitant of the United States pays each year to the railroads $3.50 for passenger tickets and $10 for freight bills.[2] This $13.50 is the railroad revenue per year per inhabitant for our average citizen. This traffic revenue per citizen of the zone of traffic we shall have for our line. We can depend upon it, provided the citizen's condition is average for America. His poverty or prosperity are factors. His lineage or racial tendency is a large element in the revenue this citizen will give a road. If the citizen lives in Florida he will eat and wear less, and his life will be more primitive, than in Minnesota. He will also travel less. The average passenger revenue for railroads per capita of all southern States east of the Mississippi River is but $1 per annum, and for freight but $3.50 per annum.[3] But the average passenger revenue for all northern and western States is $3.50 per annum and the freight revenue $11 per annum. This difference is due to both racial and climatic causes. The Saxon requires more railroad service than do the Latin races. Climate cannot explain all of this difference. The Pacific States have a mild climate, but not a large proportion of southern races. The passenger revenue per capita per annum there is $5.50—the largest of any section of our country.

There is a broader law for traffic than the amount per capita per annum. This law is based upon the number of inhabitants tributary to, or tied together by, the road. For example, if the line has at each of two terminals 10,000 inhabitants the inter-relations of these two cities give a certain traffic. Now if it be possible to change the route so as to have at each terminal a city of twice the former

[1]Railway Economics, by H. T. Newcomb, page 60 *et seq.*
[2]Economic Theory of Railway Location, by A. M. Wellington, page 103.
[3]Economic Theory of Railway Location, by A. M. Wellington, page 105.

size or 20,000 inhabitants you have increased your traffic—not *twice* but *four* times. The general law of traffic is this: "*Traffic varies as the square of the tributary population.*"[1] This law is based on statistics. Fig. 1 shows the graphic representation of the law for 25 years, covering a period of some fifteen years before and ten years after the law was first propounded. This diagram was made after Mr. Wellington's death. The law is probably as nearly correct as any such general law can be.

Thirdly, how much traffic will the future add to that already in sight in addition to that which may be speedily developed? This is a difficult question. The late D. W. Washburn, ~~then~~ Chief Engineer of Mr. Jay Gould's new lines in the southwest, laid down the ~~rule~~ ~~that~~ no railroad man could predict traffic for more than five years in the future. This must be

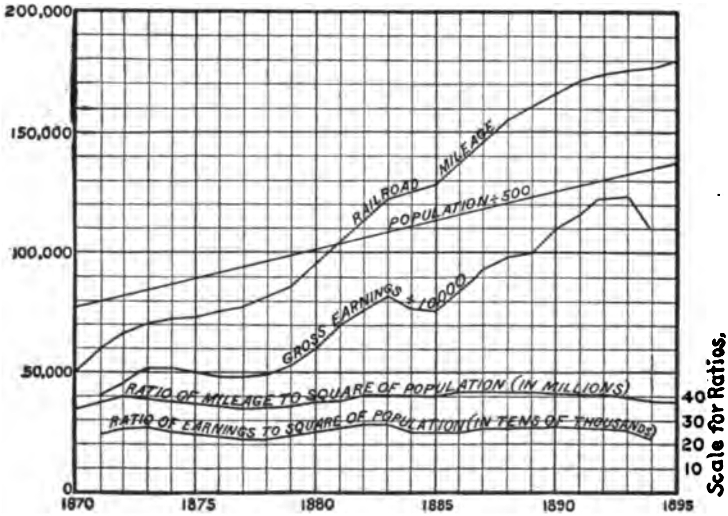

FIG. 1.

taken as the opinion of a man who was a brave and brilliant guesser. For an uninhabited semi-desert, sometimes timberless and with mines that are rumors merely, the law has merit. Often we could not tell even where water could be had—that first requisite for settlement.[2] Not all lines are desert ones. From what has preceded

[1] Economic Theory of Railway Location, by A. M. Wellington, page 713.

[2] In Texas, the T. & P. Ry. crosses the main divide, between the Brazos and Colorado rivers, where the ground is very hard and has a subsoil of cemented gravel. The cut was taken out by blasting to aid the plowing. The work was done in the winter of 1880-81. This was the first grading of which the writer had charge. A number of prairie dogs were taken out. They had hibernated there in their holes. There were so-called "Wet Weather Ponds" a few miles east. These were shallow pools after heavy rains, but dry the greater part of the year. There was no water there for

we have seen that forests can be rated in millions of feet of product, mine products may be known by at least a conscientious guess based on facts which may be gathered with care, and the products of the soil are not beyond the hope of estimating. When our new main line runs through country where it is not entirely the forerunner of civilization the question is clearer. We can reason by analogy from the known—little though it be—and predict the unknown. In a region somewhat settled, traffic may be predicted five years ahead with some hope of general accuracy. The laws of growth in traffic, and the revenue per capita, we have seen. In our own, a growing country, the traffic increases. How fast? How soon? Will it come our way? These are the critical questions. We may finally rely upon this principle: *To secure the most traffic per mile of road, tie together the largest population and products possible per mile of road.*

We have considered the amount of traffic. The kind of traffic must be also considered. We are not now speaking of *class*, i. e. whether lumber, coal, grain or manufactured product. Traffic is of three *kinds* in railroad parlance: (1) Local, (2) Joint, and (3) Through Traffic.

Local Traffic is traffic which originates at a point on but one line of road, and is for delivery to another point on the same line of road only. Local traffic is non-competitive traffic. It is traffic to which but the one road has access for receipt and delivery. Some consider that traffic is local to the road where that traffic originates. It is that road's local traffic although the destination of that traffic is on another line. Some consider that it is then local traffic also to the delivering line. This seems hardly in keeping with the term or the spirit of that class of traffic. It is supposed as a rule that one half of all traffic is local traffic. Conservative managers consider it the most valuable half.

Joint Traffic of a line originates on one line of railroad and by a connecting road is delivered at its destination. By a mutual agreement one or more intervening roads may be admitted by these two roads to joint traffic benefits of this business. It is then joint traffic to all the roads concerned. Joint traffic is not strictly competitive nor non-competitive business. It is business which must be divided.

Through Traffic of a line is competitive traffic neither originating on nor delivered at its destination by the line. It is originally turned over to the road by another road, and when the boundary of

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grading purposes. The contractor had a weak well some distance to the west, but hauled the most of the water needed from a distance. Water was looked for everywhere. This hard main divide was thought so unpromising that it was not considered. Now the town of Roscoe is located there, and has plenty of good water from rather shallow wells. It seems to be a flourishing farming community. It may be that, from the finding of prairie dogs in the ridge and from the existence of the wet weather ponds just east, the existence of water at a shallow depth between these two points should have been expected.

the territory served by that line is reached, the through business is then turned over to still another road which may deliver it. Generally speaking, through traffic means the traffic that passes over the entire length of the line in a given direction, but this is a loose construction of the term, and would include local traffic between terminals. Through traffic is most easily obtained and most readily lost. It is strategical traffic. It is unnatural traffic, sometimes, and depends quite as often upon thorough traffic management and splendid transportation efficiency as upon location or constitution of the railroad line.

COST OF CONSTRUCTION.

Having considered the traffic features of our line we must, in this connection, and before deciding whether we should begin to survey a line, form an idea of the cost of construction, operation and maintenance. Such costs are estimates, guesses, perhaps, but guessing is the genius of experience and those who cannot guess should not say it cannot be done. What construction engineer has not seen some old grading contractor, who could not read nor write perhaps, but who would walk over some five or ten miles of grading he thought of contracting to do, and guess at the average number of cubic yards per mile as closely as a table of "level cuttings" would give it! An experienced constructing engineer will look over a profile when made on a "plate" (scale) to which he is accustomed and estimate the grading on a preliminary line closer than that preliminary will probably be to location quantities.[1] What a construction engineer can do with a profile a locating engineer can approximate to on reconnaissance. He largely does this by judging how the proposed line compares in its country traversed with other lines he has before reconnoitered, since built, and whose quantities and cost he knows.

The cost of operation is comparable to existing lines of like alinement, gradients, soil and climate. The cost of maintenance is even more readily obtainable by comparison with a line whose ties, bridge timber, rainfall and soil resemble more or less closely the line contemplated.

How does the length of the line compare with its competing routes? By length is not meant the number of mile posts along it but the "equated length"—the resistance length. Between Lake Erie and New York City, how do the Central and Erie roads compare in length? The Erie is more direct. The Central has lower

[1]The first approximate estimate the writer ever made was on some sixty miles of line, using tables of level cuttings. It seemed to average 14,000 cubic yards per mile of grading in the cross sections. Handing the estimate, with the profile, to the Chief Engineer, that gentleman looked rapidly over the profile and said: "I *think* you have made a mistake. You are too high." A brief examination showed that in getting the average per mile a mistake was made. The corrected average was 13,400 cubic yards. Later, the writer learned to estimate by looking over the profile within about 10%, on plate "B." On plate "A" he cannot estimate at all.

gradients. Whether the resistance to traffic between Chicago and New York City is less by the Pennsylvania than by the New York Central may be a question. It is resistance that tells the desirability of a line; it is the resistance that uses coal, and consumes time. Other things being equal, the shortest line offers the least resistance. But the shortest distance between two points is along a straight line. *Therefore, never depart from a straight line between terminals of railroad location unless you have an economic reason for doing so.* This is the first law of railroad location. It applies with particular force to new main lines. Be sure to get the maximum average business per mile, and keep the "inside line." Distance is worth money.

Can the company furnish the money to build the line, and carry it through that season of poverty which generally follows the close of construction? Many roads fail to secure funds very late in their construction. This means bankruptcy, or a selling of securities at a great sacrifice. Needs grow as a road is constructed. Many expenditures are justifiable but not foreseen. The early days of construction are "flush days." Feeling rich we build a better road than first intended. How much money is there now? How much more can be borrowed on bonds at par and at what rate per cent. per annum? It is not wise to build what one cannot control, that is,—own over one half the stock, unless you plan to sell in advance of completion. Better abandon the idea of building than to overreach. Counting on government or state or local aid, or on the promises of other roads or of private parties, has embarked excellent railroad men on new construction only to wreck them. Consider the late Thomas A. Scott and the Texas & Pacific Railway. Aid from Congress was his final hope, and he lost. To struggle on with a line quite hopelessly embarrassed for means is most heart-breaking. Never mind the successes—all have heard of *them*. How many failures are there to each success? Leave "wild cat" railroading to others. This does not bar out cheap initial construction where desirable. If you have a good project, showing clearly a profitable traffic, low cost of construction and operation, and a strategic position, and have not the money, abandon the idea of a railroad. This is the investor's attitude. Economic location of railroads is different from mere promoting for others to build, and has little if anything in common with it.

In closing the subject of New Main Line construction it is well to say that seaports or even lakeports cannot be moved to other harbors, even though quite adjacent. History has shown this. Nor is it wise to try to move towns. A town is hard to move. It may not always survive transplanting. Spite has cost roads much in this direction. It is not enough to approach a city. Go into it with the track, and while doing so get into the most convenient position for traffic to flow to your line. The West Shore ignored cities. The Union Pacific built a great deal of line west of Omaha

but never reached anywhere with it. The Texas & Pacific built some seven hundred miles west from Ft. Worth and stopped at a certain "soap weed," where the Southern Pacific Railway would pass later. The grading was completed to El Paso—90 miles away. That was sixteen years ago. There is no town there yet. Terminal points of importance at each end are almost imperative. Local traffic of considerable magnitude and of not infrequent occurrence must exist. New ports or new routes for commerce are unsafe investments. In locating a new main line be sure to plan to get the line of least resistance most accessible to traffic. *Always make future competition pay more for future advantages over the line now located than those advantages are worth.*

EXTENSIONS OF MAIN LINES.

The Extension of a Main Line is a simpler case than a new main line. We are extending from the known to the unknown, and can logically deduce from the operated lines what the traffic, cost and financial standing will be of the main line extension. The same principles concerning traffic are true as in the case of new main line, except where the conditions clearly forbid it. The cost of construction and operation can be readily deduced from experience on the present line in operation. If the extension be but a few miles it may add but little to movement expenses. Usually a main line extension is an operating division or more in length and is simply an added division of thinner traffic.

There is one most important point to be considered in such extensions, and the principle is applicable also to branch lines: *It is not necessary that the extension be profitable within itself.* It need only increase the total profits of the company. In fact an extension that will pay its own expenses is profitable, because it increases the business of the parent main line. This is not only due to the development of new industries and the increase of products naturally arising from main line extension, but to the multiplying of intercommunication by an increase of traffic units—towns or individuals. This fact, together with the growth of business, makes main line extension often justifiable. By extension, we must mean going farther into the country which is tributary to the entire length of the existing line. The new traffic can be added to the traffic of a former main line at its terminus and transported over the road at a much less cost per ton than on the main line extension. Such increase of volume of traffic with no *corresponding* increase in operating expenses on the former line gives the value to extensions. This is the law of "Increasing returns."[1]

It may be said, in general, that extensions, branches, etc., of a railroad do not participate fully in all items of cost of operation. Some 30% of the operating expenses are administration expenses. Probably one-third of these administration expenses will not be at

[1]Railway Economics, by H. T. Newcomb, page 55 *et seq.*

all increased by the extension. Such expenses comprise those of the general office, commercial agents, advertising, and many miscellaneous items.

CUT-OFFS.

A Cut-Off for a Main Line is really a relocation rather than a location. The cut-off and the circuitous route may be both operated, or the latter may be abandoned. Short cut-offs usually cause the circuitous route to be abandoned unless by so doing traffic is unwisely lost. If the circuitous route be retained, the total benefits from the traffic it alone furnishes must justify the total added cost due to its operation. Therefore we may disregard this circuitous route, as the economy of retaining it in operation or not must stand or fall on its own merits, and consider the cut-off line as doing away with the circuitous line.

The traffic being the same as on the existing line, and the cost of money to the company being then well known, the question whether a cut-off is economical is practically a question of change in cost of operation. Given the volume, classification, direction and speed of traffic, can there be saved in cost of operation of the entire road as a whole, and in increased earnings due to this betterment and facilities, a sufficient sum to warrant the definite expenditure the cut-off will demand? From the survey and the market price of the securities of the road the fixed charge of this cut-off is at once found. Unlike other new lines, this information is not at all problematical. The traffic is definitely known from the business being done on the road. The cost of doing that business on the present line is known or may be known through intelligent observation and accounting. The increase of business which we may hope to secure because of the better line we will have when the cut-off is in use, through a saving of time, for example, is a question which, as in a new main line, is not definitely determinate. However, one can disregard this new business, and should do so, perhaps, unless it is a marked increase on former business, for the error is on the safe side. If new traffic be secured along the line of the cut-off it must be credited to the cut-off and has such a value to the road as the traffic turned over by a branch line.

The change in cost of operation of a road is the important and difficult question in the case of cut-off lines. This cost by items is a function of the management of the road. It would probably cost the Great Northern Railway less for movement expenses, item by item, than it would the International & Great Northern, for the former road holds the record for the lowest cost of moving one ton one mile, while the latter is a thin traffic line. The cost of maintenance, item by item, will also vary in some degree, largely as the kind of road and its management. Where maintenance is cheap, changes have less effect upon maintenance. The latter road just mentioned is the road which shows the lowest average cost

for maintenance of any road in this country, viz., $26 per mile of single track road in 1896, as against $2,600 per mile of double track road for the Pennsylvania Lines.[1]

BRANCH LINES.

A Branch Line differs from a main line having the same traffic and traffic revenue, inasmuch as the latter stands alone and is isolated, while the former is a part of a whole. A branch line is supported and part of its expenses gratuitously met by its parent main line. It contributes earning power to that parent line and must be weighed in merit with it. A branch line may be in itself losing money; its main line may be in itself barely paying expenses, while as a branch and main line taken together they are reasonably remunerative to the capital invested in them. In this prime essential a branch road differs from a main line. We speak now of branches and main lines actually—in the traffic sense, and not in the fiat sense of organization. A branch line may reach but 10,000 people and its main line reach but 100,000 people. The branch adds but 10% to the tributary population, but traffic varies as the square of the tributary population, therefore we have increased the traffic 21%. As we have already seen, this increase in business is at a much less increase of cost of operation, possibly a very slight increase. Branch line traffic as a rule is very light compared with main line traffic while the cost of construction and maintenance is much more nearly equal to that of the main line.

There is another quality of a branch line which must not be overlooked. Its mileage has no benefit within itself, practically. Get the traffic to and on the main line by the shortest, cheapest line possible. Otherwise cost of maintenance and some train expenses are being duplicated. *Strike the main line as quickly as possible without increasing cost to save distance.* Come in squarely, and not on the hypothenuse. Traffic distance is made, without maintenance of way being added. The writer knows of no other case in practice where increasing the distance the traffic is hauled is economy for the railroad company.

Branch Lines are of several kinds. It may be a Branch Line to an important town, situated ten to twenty miles away. Such roads are sometimes called "taps." Such branches make the main line liable to the suspicion of being located wrong, for main lines should seldom leave an important town off its line, and then find it economy to run a branch line to that town. Such a plan is certainly questionable, although circumstances may warrant it. Obviously, if the branch is to run to a certain important town it is economic and will generate traffic if we start the branch from the main line at a town of considerable size. For tieing these two towns together creates traffic through induced inter-communication. This condition will modify and must be balanced against the

[1]Railway Track and Track Work, by E. E. R. Tratman, page 3

quickest, cheapest route from the important town to the main line. Again, if we start a branch from a town of goodly size we have not increased the number of our yards, and therefore save in time and switching cost. Putting a "Junction" a few miles from a good town is, in itself, bad railroading. It limits the town, whose interests are in common with the railroad interests in many ways; and it costs the railroad time and money. It benefits no one, and can only be justified through cost of construction, overbalancing traffic benefits and increased operating expenses. It is too frequently done because of the unschooled temper of some railroad official who would rather have his own way than make money for the company employing him. It is a rule of railroading that crippling or killing a town injures the railroad to which that town is tributary. This is so generally true that it may be laid down as a law that for either the town or the railroad an injury to one injures the other. This is common sense, and common sense is usually good railroading. Roads cannot stay out of important towns, but roads must diligently seek a large local, rural and village patronage, local to the road if possible. The fallacy of relying upon large cities and through traffic is now evident. Competing lines reduce rates too much. Try to pay operating expenses with local traffic and then fight for joint and through business in large cities for dividends and sinking fund with a chance of winning in the end. Rate wars have less terrors then. We tend to over-develop cities. It is of questionable benefit to the country or to the railroads. Our city population is increasing now about seven times as fast as our rural population. This is not well for railroads, on the whole.

A Branch Line through new but well settled territory, with industries developed and towns well established is the ideal branch road. It is a feeder. It is not a "tap," as the last case considered. This should be a local line. Serve all of the towns, manufactories and inhabitants in the best way possible for themselves and the railroad, considering that the interests are entirely mutual. Assuming that new territory means that no other road occupies it, so serve the interests of the community that no other road needs to occupy it, or ever can and get out of that region other than a vulgar fraction of what the first road secures. Grades can be wisely sacrificed, especially if undulating ones where depots can be on the summits. Do not waste distance, but here, if anywhere, we may sell distance for increased traffic. That is to say, on a local branch road one can probably afford to go to a manufactory having certain, constant, established business even if it be out of the way. Help the factory and it will support the railroad. Go where a handy depot location can be had for a village, and despise not a covered platform for a flag station at an important highway crossing between villages some distance apart. The locating engineer on local branches needs to keep in touch with the division freight agent or the general agent for that district.

A Branch Line through competitive territory is one invading

the traffic zone of an opposing line. The tactics must differ from the case just mentioned where the country is new territory for railroads. When entering an opponent's territory try to invade territory occupied by the weakest of those opponents, when the country is equally productive in any case. It is fighting for traffic. Fight the weaker opponent and it will cost less money. See which of the opponents has its stock quoted lowest, has the lowest credit, and also note which has the least aggressive management. The South Pennsylvania Railroad did not succeed in its fight with the Pennsylvania Railroad. It is said that even the Nickel Plate came near not selling its line to the Lake Shore. The late Mr. Brice would not have recommended such tactics continuously.

The late Mr. Gould wished a line from his existing system to Denver in 1885. He bought a bankrupt road as far as Salina, Kansas. He started to the north of west from Salina, paralleling at a good distance the Kansas Pacific, a line of the Union Pacific, and heading off the Central Branch of the Union Pacific Railway. He was too strong for the crippled Union Pacific with its stock quoted low, a management not aggressive, and the National Government as a partner in the business. The line to Denver showed no probability of strong opposition. As a condition of a lease renewal of the C. B. U. P. to Mr. Gould's system of roads, he agreed to stop work on that Denver line. He then bore south of west from Salina paralleling the Kansas Pacific at a good distance as before, but heading off the Atchison, Topeka & Santa Fe on the route they would naturally take to Denver. Denver was a city toward which all lines were then heading. The A., T. & S. F. stock, selling in the 90's, as the writer remembers, was a Boston stock, not listed on Wall Street nor susceptible to attacks. This was a live road and had an aggressive management. They paralleled Mr. Gould's line all the way to Denver and fought him all over the state of Kansas whose legislature and people were most friendly to the road. The Missouri Pacific had a stronger fight when it attacked the Santa Fe than the Union Pacific was able to make, and its own lines in Kansas are worth less because they have been paralleled and cut into more by the stronger rival. The map, therefore, is not the only criterion in selecting localities for the construction of branch lines. The stock market and the repute of the management of the lines which will also occupy that country are important.

A Competitive Branch road must compete successfully. Its facilities offered the patrons must be better. It must get nearer the traffic. If the other line is on the outskirts of a town the proposed line must go through that town. If his depots are in the residence district yours must be in the business district. Buy the way through a street, have a finer passenger depot than his and nearer the shopping district, have a more commodious freight depot, close to and on the same side of the main track as the jobbing district. Have switches near factories and storehouses, and run spur tracks

to factories and mills, or aid the owners to do so readily. In short, get the "inside track" for traffic by making it easier, quicker, cheaper, to patronize the new road. Be inviting to a passenger business and indulge its ease. Be helpful to freight business, and remove every resistance possible to its flow. Trains must run at more convenient hours and get the patrons to their wholesale market in less time. Distance is worth more than on a local line. Gradients may still be sacrificed if it can be done by using a heavier class of engines. In this case of Competing Branch Road more capital is needed, a better class of road, and more railroad knowledge than for the first line built into that territory.

There are Branch Roads to new mineral districts. Here gradients are of prime importance, usually, and distance losses must be allowed. Time in transit of traffic is of less consequence than cost per ton from mine to market. Colorado has many such lines. There are Branch Roads over semi-deserts to revenue producing districts beyond. Since desert in this country means rather featureless country of not expensive obstacles, we may safely assume that as a rule such lines have few sags in grade line over 25 ft. in depth, and that to run straight and "chop" the grade line is the wise plan. Even though the country be "ragged" for a distance, the writer has found that "jumping" it generally beats turning and twisting through it. It is no use to lose distance in a country which has no drainage system and is of only moderate difficulty. It is no use to turn and go sidewise up the only little ridge there is in that whole region just because it "looks badly to pay no attention to it." The shortest distance through gives the least number of cubic yards, and the gradient will help less than the hypothenuse distance damages the road. Run straight if possible from where local business ends to where local business begins. Cross deserts as one would the sky—straight.

SUMMARY.

Finally, it is a general truth, that for the Locating Engineer the Main Line is more his especial province. On the Branch Lines he must be a railroad man as well as a locating engineer. This may seem strange, but young locating engineers do better work on a main line than on a branch road. Youth, and the railroad "Magnate," belong on the main line. Branches are more human, less mathematical, more scientific and require the use of broader faculties than do the treatment of main lines. Main lines are the creators of railroad systems, while it is clearly true that branch lines tend to be the saviours of those railroad systems in their later growth. The value of the traffic to the company arises from profits in hauling it over the main line, it is true, but the branch line must solicit and secure the traffic before the road can profit through hauling it to market. The traffic problems of the branch line are more determinate than those of a main line, but the traffic is

more chary and liable to discouragement. It is retail trade, and not in the strongest hands. It is far more a function of the individual patron, of the soil and of the minerals found there. The cost of branch lines should be a definite quantity, the rate of interest easily known, and therefore the fixed charges can be known in advance. This fact is peculiar to most branch lines. The cost of operation of branch lines per mile bears no analogy to the volume of traffic as compared to the main line. Not wear but decay dominates the maintenance of track and structures. Not mileage but hours really fixes the pay of employes. Branches are uneconomical in maintenance and movement expenses. These are important facts and must not be overlooked. The superintendent who tries to operate and maintain at the certain cost per ton mile on the branch lines he does on the main line will quickly learn a lesson. It has been done, but the wood in the lines soon perished through decay and a revolution in policy had to follow. The value of a branch line arises from that increment of traffic it adds throughout the length of the main line without adding a commensurate amount to the cost of operation of the main line. This is a potent factor in causing it to be economical for strong existing lines to acquire local and tributary roads.

The character of the road must bear, as we have seen, a proper relation to the traffic. But the amount of funds available for construction often influences the degree of excellence of construction. This adjustment of the quality of the road to the funds available is the trait peculiar to American engineers. It stamps them as better railroad men than their fellow engineers in most other countries. Any engineer whatever can borrow plans of a first-class road, hire scme experienced assistants and build a "banner road" if there be money enough. To build much road with a stated meager sum known at the start and get a road to operate successfully and *rebuild itself* is high art in railroad engineering. Novices need not enter here. Good railroad engineering is not indicated by the high cost per mile, but by the fact that for each dollar spent more than a dollar in earning power is created. What is good work? Is it not a good adapting of engineering methods to circumstances? It does not mean high class masonry, or rock ballast on new track. Does it not often happen that lines so built must borrow money at ruinous rates before the first train has run over the road? A good fight may be made with but few soldiers—or few dollars. A cheap line has been much tabooed. It should have no terrors for the engineer—certainly not for the American locating engineer. The much we have done with the little at our command is our glory today. Now that our nation, largely through cheap lines instead of no lines, has become much stronger financially, let us not despise the ways of poverty too soon. Expenditure must be fully justified by earning power. The class of road must fit its traffic.

CHAPTER II.

Reconnaissance for Route.

The class of road having been decided upon, the terminals fixed, and perhaps one or more intermediate points, the next step in natural sequence is the reconnaissance for route. We take for granted that the company through its president, with the aid of the chief engineer, has determined the class of road and the general territory it will occupy. We infer that the chief engineer, in person, and by the aid of others, has determined approximately the kind, direction and volume of business during the first five years as a basis for economic location and construction of line. It is conceded that future business beyond a term of five years cannot ordinarily be safely estimated. Whether this information be assumed or whether it be the result of careful study of the trade conditions, it must be considered as a part of the instructions of the locating engineer whose duty it now is to make the reconnaissance for route. To survey the line with no idea of the business expected, either in direction or volume, causes a chief of party to waste largely the cost of survey. Conditions outside or beyond his line of survey need to be taken into account; and we assume that they be given him instead of his being obliged to attempt some approximation of them for himself.

On large railway systems the usual instructions to the locating engineer often read as follows: "You will proceed to A, and make a reconnaissance for a route from that point to X. We wish to pass through B and C. We are obliged by statute either to pass through D or to stay over five miles from D. When you reach the O. & P. Railroad you may cross their track at grade, but in any case a connecting track must be provided. When you reach the line of the R. & S. Railroad you must either go over or under, as we will avoid a grade crossing of that road. The class of road will be the same as the W. V. R. R. which you located. Consider, therefore, distance to be worth $5 per foot.[1] Use no curve sharper than 3° unless unavoidable, and your maximum gradient we desire not to exceed 66 ft. to the mile in either direction. Unlike the line last mentioned, the preponderance of traffic will be from west to east. Reduction in ruling gradient or reducing the length of each maxi-

[1]This value given for distance is for distance which includes equating for curvature and for rise and fall. It has been a unit value always fixed by good roads for new lines of their property. The custom is now falling into disuse. Some companies never use it now, but solve the problem in detail in each case.

mum gradient which is against eastbound traffic is most valuable. Communicate with this office, should you find on close reconnaissance that these curvature and grade limitations are not wise. Where you find it best to exceed these maximums of grade or curvature inform this office." With the letter fixing the class of road as similar to one he has already located, and giving a value to distance and a limitation to degree of curve and gradient, the problem is now entirely within the province of the locating engineer.

After receiving his letter of instructions the first need is a map of the region covered by the instructions. It must be of the very largest scale obtainable, and as accurate as possible. Any map whatever is far better than no map. A large scale map even if far from complete is preferable to a map on a small scale for the omissions can be filled in as you go along, and a good map may be thus obtained. In the Middle West, state maps can be had with one inch to each township, and county maps one inch to each mile. They should be mounted on cloth before using, otherwise they are torn by the wind. State maps showing mean average rainfall are valuable, as that is a guide for height of grade and size of openings. Maps showing the drainage area of different rivers in different colors show at once where the main summits are. Should there be a relief map accessible, a study of it is always valuable and facts from it should be noted on the ordinary map. Having a good state map and as many county maps as are at the time obtainable, you must procure missing maps as you pass through the country—so far as maps have been made.*

INSTRUMENTS.

The instruments needed are the usual pocket instruments, and others adapted to saddle transportation. They may consist of field glasses, compass, aneroid, hand or binocular level, watch, protractor and scale.

Field Glass.

The army field glass has one application that the writer has not seen mentioned. A good glass, which is quite free from chromatic aberration, will show where most "cul de sacs" exist. These are a bugbear in reconnaissance. A colorless pair of glasses as adjusted for the distant sight (a glass "cool to the eyes") will show the fatal, distant range of a "cul de sac" to be more blue in color and therefore more distant. As it is more distant than the rest of the hill it is therefore not the same range and a warning is given that what

*There may now be obtained from the Director of the Geological Survey, Washington, D. C., maps for various limited portions of this country. The maps are to a scale of one inch to one mile, and are sold at five cents each. They cover a greater portion of the Eastern rather than the Central or Western States.

seems easy ground is a "pocket" in America, or, as our European brother would say, a "cul de sac." Inferior glasses will not do this.

Prismatic Compass.

A prismatic compass is needed, and one that shuts up compactly enough to go into the second watch pocket of one's trousers is much better than one carried in a case. Such a compass (Fig. 2) the writer chanced upon some years ago. They are now made in America. The reason for using a prismatic compass is that bearings can be read to objects sighted. The prismatic compass reads to quarter degrees. Its prism magnifies. The circle is read under the needle by reason of the optical properties of the prism. The object is seen through the slit as superimposed over the circle at the graduation to be read. The prism should fold up and the forward sight form a cover to the compass box when closed down. It is graduated in the French manner from 0° to 360°—a desirable way for reconnaissance, as you need remember only a number for your course and not two letters as well. Subtraction of courses gives the angle at a point. But great care must be taken that you do not record the angle in the wrong direction. Even greater care must be taken that an error does not occur in converting the prismatic reading to a needle course for the use of the ordinary compass box of the transit. There is a great source of error in a prismatic compass owing to the fact that the card weights the needle. It is like a poorly magnetized needle. It is best to turn with the compass around to the desired course first from the right, for example, and read the course. Then turn toward the same course from the left. Halfway between the readings is nearer the truth, although repetition is necessary to show this. Of course, a prismatic compass must be held level while the needle is settling. Some horses will stand quietly so you need not dismount to read the courses.

FIG. 2. Prismatic Compass.

The Barometer.

An aneroid barometer is indispensable. It is an instrument of approximation—not an instrument of precision. Its zero should be set at the zero of levels for the line and its reading checked on the nearest known height adjacent to the initial point. It should have a movable circle graduated for elevation in feet, beside the usual

graduation. The wide fluctuations of this instrument due to atmospheric changes are well known. Repetition is the usual safeguard against large errors on this account. If the reconnaissance be made from a pack-train camp, and a second aneroid barometer be kept at that spot during the day and read hourly, these variations due to atmospheric pressure can be eliminated from the barometer readings taken in the field. It seems probable that, if a self-registering aneroid or barograph or a mercury cistern barometer could be kept at camp and its readings used to reduce the aneroid readings taken at corresponding times in the field, the results would be the best obtainable.

Some engineers use no aneroid barometer. Other engineers use any aneroid barometer, seldom test it and profess to believe its readings without correction. Neither class of engineers is following the wise course. In the future, it is likely that more intelligent use will be made of these instruments, and their variations due to atmospheric changes will be separated from their variation due to altitude. It has of late years appeared to the writer that a barograph, similar to those used by European engineers in topographic work, is a possible solution. Our own weather bureau stations in this country use such instruments and they seem to merit trial by locating engineers. They are portable, being about 5 x 6 x 12 ins. They have no delicate parts, need no setting up, and no attention seems to be needed on moving days of camp life save to slip a cork on the pen point to keep the ink from blotching the paper on the cylinder. The barograph costs about the same as the aneroid.

The individual barometers are not of equal accuracy. Trial alone can test them. The same barometer will be accurate for some elevations and inaccurate at other elevations. Some have a zone of inaccuracy. For example, they will not read correctly when the elevation is from 2,000 ft. to 3,000 ft. above tide, but read accurately from 0 to 2,000 ft. and from 3,000 ft. to the limit of reading. Some barometers "catch" or "hang" at times; i. e., the indicator or needle reads 1,950 ft. persistently up to 2,000 ft. when it suddenly jumps to 2,000 ft. An aneroid must always be tapped gently with the finger to insure against this error. Always hold the barometer horizontally and face upward in reading, as position causes errors. Most good ones are "compensated," but it is best to read yours in connection with a thermometer and a standard mercurial barometer to find out whether it is balanced for temperature. The hourly variations of the aneroid give most trouble in railroad reconnaissance. You can start right in the morning from a known height. You can read the elevations desired at certain recorded times. You may know that your barometer was rising or falling at a certain rate per hour in the morning. At noon, as you lunch, you can get its rate of change again. Should you remain in the same place or at the same altitude for some time during the day, you can again get a rate for the barometer. Knowing the rate at several times during the

day you can correct the observed elevations so as to give them greater probability of accuracy.[1]

With a self-registering cistern barometer at camp during the day, with which to compare the aneroid morning and night, better results can be secured. Two aneroids, one in the field and one in the camp, read at intervals are better than one. A barograph or a self-registering barometer in camp would surely remove many errors. But, neither field practice nor theory, so far as generally known, shows what may be accomplished in this direction. We must avoid careless confidence in aneroids and at the same time remember that any barometer is better than no barometer as a check on estimation of elevation by the eye.

The Level.

The Locke hand level needs no description.

The binocular level combines the uses of a hand level and a field glass. It is simply a greatly improved hand level. It is used when necessary to carry the line of levels from point to point without a rod, and with the natural height of the eye of the observer as the constant quantity to be successively added to or subtracted from the known initial elevation. When a line of levels is carried from a point of known elevation to a point whose elevation is known only by a barometric reading, the binocular level gives a good check upon the barometer reading. Unless you have a rod and a rodman such checking is not close, because natural objects cannot be found to mark sharply and hold the level heights defined by the cross hairs. A self-reading rod with even an inexperienced man as a rodman is a great aid at critical points. We do not use our hand levels or binocular levels enough on crucial parts of our reconnaissance work. It is not very difficult to run a line of hand levels up a five or ten-mile hill with the aid of a man and rod, and get as near the correct result as many of our poorer levelmen will do with a wye-level.

The greatest use of the binocular level is not in determining the elevations of controlling points but in finding out the slope in easy country. The height of the eye of the average man is about five feet. Ascertaining your own height of eye, and wishing to determine the slope of a hill, you sight to some plain and small object

[1]The aneroid barometer drags in its readings. The one carried by the writer recorded at one moment the elevation where that aneroid had been about twenty minutes before. Therefore, in ascending a hill consecutive readings of different points were too low, while in descending the hill successive readings at various points show too high. Therefore, if but one reading was taken at a summit and that one taken as soon as that summit was reached, the reading showed that hill too low. This particular aneroid showed errors generally 25 ft. in hills met in 66-foot country, i.e., country practicable for a gradient of 66 ft. per mile. This error through dragging of the aneroid readings is one of the most fruitful sources of disaster in aneroid use.

on the surface of the ground and advance or recede until the cross hairs are in front of the object. As you must always know how many of your ordinary walking steps make a hundred feet, by counting these steps from where you observed to the object you get the rate of ascending grade. By observing this gradient at several points as you go up the hill and at each time where the slope seems an average one you have information which checks your observation and judgment. The barometric elevations of controlling heights and their scaled distances apart may give another check on the slope.

A protractor and scale are required for the purpose of platting new data on the large scale map.

DISTANCES BY TIMING.

A watch is needed to aid in judging distances by the time consumed in traversing them. An experienced saddle horse whose speeds at his various gaits have been learned accurately by previous timing will be of great aid in determining long distances. Short distances must be paced on foot. Horses ridden long distances acquire an evenness of pace that enables their constant rider by the aid of his watch to get his distances from point to point almost as closely as with a stadia used on long sights. Distances so determined, like barometric elevations, need checking by repetition.

Of the horse and his trappings and of the engineer's equipment for personal comfort and safety it need only be said that for the plains or frontier he needs precisely what a scout or a member of the regular army needs in undertaking to traverse the same country and live for the same length of time in it. In an extreme case he needs a guide who is a packer, and two or three pack mules besides a saddle animal for each man. In semi-civilization, by carrying a pair of blankets and a little food, he can go alone on horseback, expecting to stop at some ranch or chance cabin. Of course a team and driver may be used and a saddle horse dispensed with. The driver should be a guide familiar with the country. This is a method that recommends itself, but is not desirable because a team cannot go over the broken ground, which is the object of special importance. A reconnaissance from a covered carriage, like an inspection of track from a rear platform of a car, is better than nothing, but it is not the best obtainable. It is a rule of the cavalry service that you can rely on leading a troop horse wherever the trooper can climb without using his hands. A saddle horse is the ideal transportation for reconnaissance work in usual country.

METHODS.

The kind and character of the work to be done by the locating engineer on reconnaissance for route will depend upon the method to be employed in completing the entire work of location. While

it is unsafe to classify methods, since methods so closely resemble the mental bent of the men who use them, there have been or now are at least three general methods of finding the close approximation to the located line. They are: First, the method of preliminaries; second, the method of close personal reconnaissance by the chief of party; and third, the method employing the stadia.

The Method of Preliminaries.

The first method is the one so often used on long lines in wild country in America. Several preliminary lines are run, often by different chiefs of party, whose notes, when received by the locating engineer, are given to a chief of party with instructions as to which line or combination of lines to use for the final location. On the Texas & Pacific Railway in the early seventies, three preliminary parties were started out, running side by side, and each with a generally specified route to follow. A fourth party followed, finally locating the line, and all four parties reported to one superior or locating engineer.

This method was used in America for rapid work in country of moderate difficulties and where Indians were to be met and supplies were to be hauled from the rear. It must be assumed that this system was quite well adapted to these conditions, for it survived. It was not economical. Three preliminary lines were run for one mile of located line. It gave more than one man an opportunity to see the country before the location was made. There is safety in that idea. Some of our most experienced engineers insist that at least two capable locating engineers shall see a located line before construction is commenced upon it. In easy country three preliminary lines give too much length of preliminary line. It rarely happens that an engineer in charge of the location of the line has four men who are capable chiefs of party. The practical outcome was that men sometimes had charge of those parties who sent in a map and a profile of a crooked, heavy line, when there was a straighter, lighter line within a short distance to one side, which they did not recognize on sight. Such an error is the worst one possible. Failing to see a good line is the worst of faults in a preliminary runner. But the worst abuse that crept into this system through the natural channels was the subordination of all reconnaissance for line on the part of chief of preliminary party to the chaining and leveling. He often stayed out of his saddle, walked along with the head chainman and looked ahead, turning the transit wherever the topography of ground he had never ridden over seemed to invite. In other words, he made his reconnaissance for preliminary line *with his whole party.* At times, "just to see what there was there," he would turn 30° to 45° to the right or left and run a "spur" line for several miles.

Many who read these words will recall such lines cut through the brush—the puzzle of the unscientific and the chagrin of the

wise engineer who knew that some brother engineer had been groping in the dark. This method by preliminaries will be used largely, save where experienced reconnaissance can be carefully done. Rapid location and construction is not conducive to economy, and is a poor training school. Good work can be done in this way. Some modification of this method, contemplating fewer miles of preliminary lines and a greater amount of reconnaissance work, is the method now most frequently used in this country.

The Personal Reconnaissance Method.

A second method used is one in which personal reconnaissance with pocket instruments takes the place of most or all but one preliminary line. That it is a cheaper method is obvious, because the unsuccessful preliminaries are not gone over by the entire party. But one line party is needed, as the preliminary is so largely done by the chief of party. It is a less rapid method than the first. Its prime requisite is an experienced engineer in reconnaissance work, who is unusually expert in the use of pocket instruments and their application to developing the topographical features of a country.

The Stadia Method.

The third method is by the use of the stadia. This method has not come into general use in America. It is a European method. The stadia had been introduced into America but a comparatively short time before railroad location work became so enormous, just after our Civil War. Being little understood, the stadia was not given the attention it deserved. Another reason against its use then was the fact that the party would be small, and small parties among Indians were not desirable. On easy plains the application of the stadia is not so advantageous. Of late years the stadia method has been used by the topographer and an assistant to supplement a transit and level line. The writer has always regarded as fallacious the expectation that the stadia would enable inexperienced engineers to make the survey, leaving to a purely office engineer the making of a final location on paper. The route must be determined by an engineer experienced in reconnaissance. The paper location in the office must be made by an engineer familiar with that balancing of grade, curvature, distance and cost of construction, which some call economics and some call railroading, but which in any case requires an engineer experienced in railroad location and its usual problems. The younger generation of engineers will no doubt use the stadia more. For short lines where the route is obviously to be found within narrow lateral limits a stadia survey may economically replace a preliminary survey. For contemplated improvement of an existing line by a slight divergence from the existing track the stadia is useful. In both of these cases it is especially advantageous because few men are needed—a desirable thing in short surveys.

The stadia is at this time a future rather than an existing or past method of preliminary survey for a railroad. It clearly has a future, however. The excellent paper prepared for the International Engineering Congress by Mr. F. A. Gelbke, an engineer of government railways at Cologne, Prussia, on "Surveys for Railway Location," shows that he uses the stadia method for preliminary survey. Probably no better exposition of stadia work as applied to railroads has been given in this country. The explanation of stadia methods does not belong here.[1]

THE RECONNAISSANCE.

Being now fully equipped, and having your instructions, draw on your maps a straight line from A to B, then from B to C and so on through each successsive point as given in your instructions. The following general law is the foundation of reconnaissance and an essential to good railroad location: *Never diverge from a straight line between controlling points given in your instructions, unless you can show definite and sufficient economic reasons for doing so.* Distance costs, and directness has value. Hence a survey made on either side of the straight lines between the "primary controlling points" A, B, C, etc, must always be accounted for by facts and reasoning which cannot be disproved. Observance of the law just laid down will save aimless wandering about for "saddles" in ridges and narrow crossings of streams.

In reconnaissance we follow too often the wagon road in easy country and some creek or river in difficult country. We do not follow that magnetic course in that country which the direction between primary controlling points lays down for us through our instructions. In short, we forget that a shot-gun is not so economical of its force as a rifle and we waste energy by not taking definite aim. From the straight line drawn on the map from A to B you readily get the needle reading of that line. Starting at A you ride on that magnetic course as far as B. Ordinarily you will find on your route before reaching B that there are obstacles which should deflect the line of road. Locate them on the map and mark their degree of difficulty and their lateral extent. Turn back at B and ride on that side of the straight line between A and B which promises a feasible route nearest to the straight line. As you ride back, whenever you reach an obstacle already noted on the straight line explore on each side of the straight line for the practicable point for passing it which is nearest the straight line. On your return to A you should have sufficient information to enable you to locate approximately the probable secondary controlling points.

We have called the points named in the instructions to the

[1]For an excellent treatment of the use of the stadia in surveying by one of its earliest and consistent friends in this country, see "Treatise on Practical Surveying," by J. B. Johnson.

locating engineer making the reconnaissance the *primary controlling points* through which the line must pass. The *secondary controlling points* are the controlling points in the topography. Their distance from the straight line between A and B depends upon the difficulties of the country when measured by the maximum gradient and the allowable sharpness of curvature. The most practicable river crossings and the most available saddles in the main divides between these rivers are often controlling topographic points. A stream whose bed or drainage is crossed by the surveyed line, and does not anywhere empty into another stream whose bed or drainage the survey will also cross, is *primary drainage* for the survey.

Plat upon the map the secondary controlling points that you have found between A and B. Draw a broken line from A to the nearest of these new points and connect each by this broken line with the next until B is reached. Naturally, the first time you passed over this part of the line you gave particular attention to the main features of the country and left the details for subsequent study. Having formed an approximate idea of these main features, you must next give close attention to details. Starting the second time from A you now ride over the ground shown by the broken line which connects secondary controlling points. Taking your compass bearing as before, you ride by the compass. The query of the present Chief Engineer of the Texas & Pacific Railway quoted on our title page and addressed to the chief of one of his preliminary parties in 1880 is very pertinent here. Always "Compass it through." It is absolutely no use to spend time finding obstacles, when you have neglected to take your magnetic course from some known point of the map. Obviously the distance to the obstacle is less important than the direction when you are riding on the line of the survey because you wish to know first whether you can go straight ahead or must deflect.

The field location of the secondary controlling points by means of angles and distances from points given on the map is important and often difficult. When a point to be located is visible from two points given on the map a magnetic bearing by the prismatic compass from each of the two known points is at once a correct location for the desired point by direct platting. Even this should be checked for natural objects change in appearance very much with change in the direction of the line of sight. This is particularly true of distant saddles showing on a sky line. The best check is by a distance and an angle. The distance is usually obtained by timing a horse from some known point on the map. The angle is measured in the field between a known line of the map and the line to the point to be now located. Or, an odometer on a wagon wheel may be used. This is more accurate than timing a horse. A pedometer is valuable if the ground be such that much of the work is done on foot. Usually the secondary controlling point can be seen from one known point of the map. Then a bearing by the prismatic compass and the time and known rate of speed of your saddle horse give an

angle and a distance (polar-co-ordinate) determination of the location. Whenever convenient, in the near future, a second timing of the horse over the same route checks the polar co-ordinate location. This method is the one most frequently used.

Sometimes the points on the map are such that the secondary controlling points are not at all visible from them. In this case locate from the primary controlling points certain "observation stations" visible from the primary and secondary controlling points. As primary controlling points are usually towns, the highest church spire, the dome of the courthouse, the standpipe of the water system or high chimney of a factory, there is ample choice of prominent objects to which a back sight can be taken from a secondary point. A sharp point or spur having a uniform vertical profile when viewed from any direction is one of the best topographical points to use. Of course when such a point is located near the pass or saddle to be used the lateral distance from the spur to the saddle can be paced or the horse timed. To locate the stream crossings on the map is not so easy. They can seldom be seen from primary controlling points and must be located from the secondary controlling points on the divides nearest each stream. A map shows the main streams, however, but does not show divides. The locations of these secondary controlling points from the primary controlling points are thus accurately made on the map from the first to the second primary controlling point. The points so platted would be of little value unless their elevations were known.

ERRORS OF OBSERVATION.

It is a curious fact, that a level plain seems to rise in all directions from the observer. No doubt different observers have their individual errors in judging slopes. The writer long ago found that he underestimates the slope of ground ascending from him, and overestimates the slope of ground descending from him by about the same amount. The percentage of error is not alike for different rates of slope. But as the error is the same for each slope, but the reverse in direction, by looking at a hill "from both ends," that is, from the bottom and from the top, and taking the mean of the estimates made by the eye the truth is found. The human faculties are imperfect machines, but when we know their errors we can eliminate them. No doubt many young engineers have early concluded they had no "eye for country" when all they lacked was the knowledge that they made no large error which could not have been corrected by training or eliminated by methods of observation. If a hill always looked from every point of view in any condition of atmosphere and whether our eyes were tired or rested, exactly five times as steep as it really was, once that fact was known and allowed for our eye for a slope would be admirable. A varying error, not a constant great error, is most to be feared. Even more

difficult than estimating slopes is the walking or riding on a magnetic course. It is more difficult than being able to locate a point after you have ridden from it by a circuitous route, that is, by the scouting faculty. The writer, in riding over a ridge on a certain course, always tends to deflect to the right about ten degrees. He is deficient in that faculty which a front axman must have well developed. It is easy to train a suitable horse to go straight by watching the compass and pricking him with the spur when be begins to veer. Once the ridge is a hundred yards behind, the course is straight again in your faulty head. These human frailties are mentioned to show that an engineer on reconnaissance must guard himself to keep from errors, and that men inexperienced in reconnaissance and in wood craft or plains craft should not be disheartened by sad mistakes of their faculties.

TOPOGRAPHY AS AFFECTING LOCATION.

Having considered the method of attacking the problem of finding the route for a railroad survey and taken up in their order the use of the instruments and the nature of the information desired from their use together with the common errors to be anticipated, we must now consider the nature of the problem surrounding us. A railroad location must be adapted to the country, the lay of the ground, the topographical features—call it as you please. You must not expect to adapt the topography to the line, nor try to build economically a line of 1% grade in 1½% country. As your instructions are presumed to fix the rate of maximum gradient and curvature, you have simply to find the most economic route using that maximum gradient and curvature.

Has topography any laws which enable the locating engineer to anticipate what he will find and thus lessen his labors? As topography must rest primarily on the geologic structure and relief, modified and acted upon by various forces, it can have no laws that are not in accord with geology. The geologic structure and configurations of the earth are not uniform and unchanging in form or in recurrence of forms as we pass over the surface of the earth. There can therefore be no topographic laws of universal application.

Observant engineers have noticed when engaged in reconnaissance for some time in certain regions that the configuration of the country followed certain sequences as they passed from one drainage area to and across the next drainage area.[1]

These local conditions are a valuable aid when once deter-

[1]Mr. M. L. Lynch, in Vol. 31, p. 82, of the Trans. Am. Soc. C. E., states that: "In a stream flowing east or west the south slope of the valley is generally steeper and more broken than the north slope. In a stream flowing north and south the east slope is invariably steeper." The writer has noticed that same law in Texas. In northern and eastern Kansas he has noticed that the reverse is true.

mined by observation, and are labor saving. It makes the steep hills on the right or left bank of streams of the same class: Therefore, the ground for the steep side is examined closely first, knowing that the other slope is easier and will quite readily give a choice of routes.

To hope to discover in one locality the order of recurrence of certain topographic features applicable to another locality or the whole of America is obviously expecting too much.

It seems plain that a general knowledge of geology with its special application to topography is desirable for all topographers and locating engineers. The configuration of the country is modified by the dip of the strata and by their hardness. A geological map cannot be platted to coincide with a topographical map made by excellent topographers having no knowledge of geology. The topography shows configuration of ground which the geology prohibits. If a locating engineer has a good knowledge of geology as well as of topography, he is better fitted for his reconnaissance work. By studying the geology and topography together, he should be able to obtain a thorough knowledge of the region in less time and with less liability to mistakes.

The first thing to fix firmly in the mind at the outset of reconnaissance is the drainage of the country you are traversing.[1] What are the principal streams that are entirely independent of all other streams of that region? Where do these primary drainages rise or "set in?" In what course do they flow in the district under consideration and what finally becomes of them? What are the principal tributaries (that is, the secondary drainages) of each and where are the sources, courses, and mouths of these tributaries? Next, what are the tertiary drainages and their locations in the system of drainage? When you have studied the streams until you can recall them clearly in their location, direction and relations with your eyes closed, you have mastered the knowledge necessary to use that drainage as an aid to traffic in passing through that country.

Locating engineers have often noticed when studying a region that a certain bank of the streams of one class had the flat slope and the other bank the steep slope. Some study of the geology of the region will, in the writer's opinion, not only explain this fact but enable the engineer to predict the forms of the cross section of a stream's drainage area. In any case, an inspection of a good map will enable an engineer to know what topography to

[1]The first words of instructions on preliminary survey the writer received were from the late D. W. Washburn, Chief Engineer of Mr. Gould's construction work in the southwest. He said: "First get into your head drainage, *drainage*, DRAINAGE." Holding up his hand with all fingers outstretched and with his pencil tracing a curved line like a contour from one finger to the next finger successively, he added: "The direction and location of the drainage is a framework on which you must hang your located line."

expect in a country at its drainage lines. A few examples are cited as suggestions of the use of a map as a limit to reconnaissance:

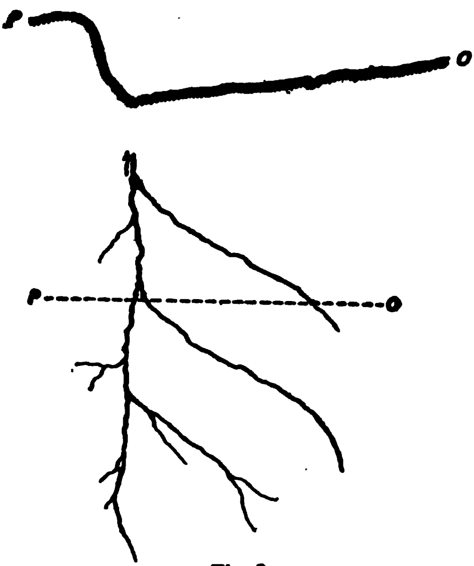

Fig. 3.

When the direction of the line of survey from *A* to *a*, for example, is the same as the direction of the primary drainage and you prefer to follow a valley rather than a ridge, which side of the stream has the flattest slope and the widest valley? Where the tributaries are very much longer on one side than on the other it is probable that the side having the longer tributaries is very much flatter. See Fig. 3. The situation both in map and cross section is shown herewith. When it is desired to follow a ridge instead of a valley, the general case remaining the same, the map by inspection often shows which of two ridges to follow. A smooth ridge with gentle slopes each way from its crest gives easy work and latitude for shifting the line for easy gradients by the use of easy curves only. Such ridges are denoted on a map by no drainage lines approaching close to its crest and especially by no dovetailing drainage from the opposite sides of the ridge.

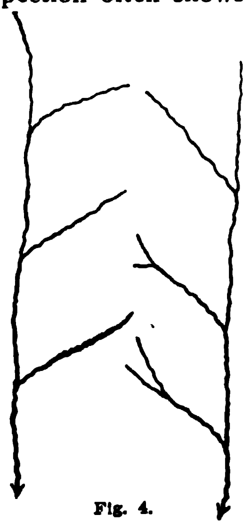

Fig. 4.

There is no ridge line between these two streams as shown in Fig. 4 without meeting considerable grading or curvature or both. On a line located by the writer in Smith County, Kansas, on such a ridge with lap or dovetail drainage as in the last figure there were plenty of 20-ft. fills on the crest of the divide. The line was broken up to save grading so that 4° curves were used, and sometimes the intersection angles were as great as 60°. The average curvature per mile for that line was 40°. The lap of the head waters of the drainage cuts away the ridge so that the fills will be heavy even where the line is located on the highest point of that ridge. The two

tributaries which are highest up in the sketch abut. This was an actual case, and necessitated a 26-ft. fill in which there was little or no opening needed as there was really no drainage area. Such gaps in a ridge make a desirable saddle to cross in, when the direction of the survey demands a line at right angles to this ridge. How such low saddles are formed by these abutting streams would be interesting to know. From a study of many of them it would seem that at one time one of the two opposing streams has been the longer and stronger and that at a subsequent period in the ages of earth erosion the other has in some way become stronger. It is surely a fact that in many of them to-day the drainage flows in the reverse direction from what it did when the most of the saddle was cut out of the ridge. The topography, as looked at carefully, proves it. When the secondary streams are broken up on the map a short distance from the ridge into several tertiary streams showing fan-shaped direction the ridge is probably quite steep. When the map shows a stream very sinuous in its course, with loops of the mule shoe form regularly following each other and with each of the same lateral extent to the right and to the left (Fig. 5), that stream is flowing in a flat valley having little descent. When the stream shows a sinuous course on a map but makes angles in some places instead of mule shoe curves and some curves of greater amplitude and irregular sizes, then the stream has not a flat valley of gentle slopes and is rubbing hard against bluffs down stream from those angles or irregular curves. For it is a principle of river hydraulics that the loops are used by the river to develop distance so as to adjust the erosive forces of the stream to the material of the banks and bed. These loops travel down the river as years go by, and when an irregularity shows, there has been a change in the character of the bank at that point and erosion is arrested there. Crescent-shaped lakes or pools indicate old river bends and therefore a flat country across which the river has shifted its bed laterally. Round lakes are apt to be found in hilly country. The shape of lakes or ponds is important in studying a map. Where drainage shows an indifference to direction, the country will be found to be quite level. The extreme case is the delta of a river (Fig. 6). In the general case this is shown by a stream, flowing to many points of the compass within a comparatively short distance. When drainage has a convergent direction the ground slopes toward that point like an amphitheatre to-

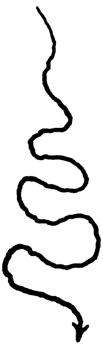

Fig. 5.

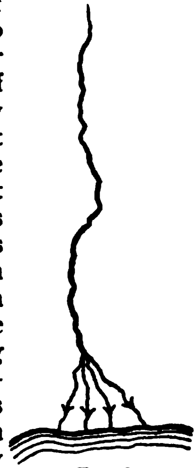

Fig. 6.

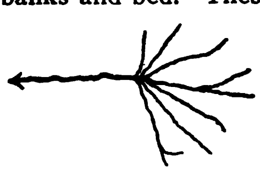

Fig. 7.

ward one point, "saucer shaped." When convergent drainage shows fan-shaped on the map (Fig. 7) with several short spreading tributaries then there are steep slopes and ugly valleys at the headwaters of the stream and the amphitheatre formation is an obstacle save when the route is the same as that of the stream draining that amphitheatre. When drainage has a divergent direction (Fig. 8) from any point, that point is high, a mound, commanding hill or a mountain.

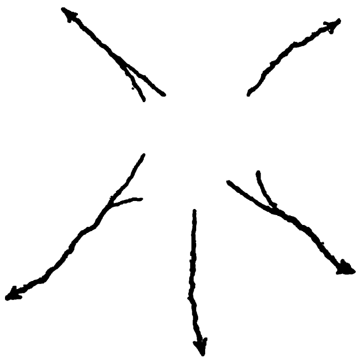
Fig. 8.

When streams approach each other quite closely on the map (Fig. 9), and the country is not difficult, the divide is lower where the streams are nearest together. This is true whether the streams are flowing in a parallel direction or not. In the case shown in Fig. 10 the survey crossed the Pomme de Terre River near Hermitage, Mo., in the Ozark Mountains. The country was difficult. A long detour was saved by using a very short tunnel where shown in the sketch. The ridge was but a few hundred feet through. No such location would suggest itself by casual riding over the country. It was suggested to the writer, by the map of the (Jackson) county. It is safe to consider that when streams are near each other, nature has done something which will enable the locating engineer to take advantage of that country. Either abutting streams or parallel streams promise low saddles or short tunnels.

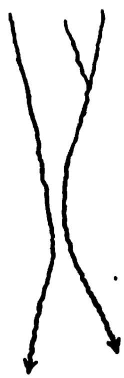
Fig. 9.

While no general rule can be followed it is usually true that either the primary drainage is in the direction of the route surveyed or else the secondary or tertiary drainage is in that direction on one side of the primary drainage. Therefore there is always some drainage "going your way." This implies that the tertiary stream on one side of a secondary stream is about at right angles to a primary stream, and that a secondary stream is ordinarily at an angle approaching 45° to the primary stream. This makes the secondary streams, on one side of the primary drainage in the right direction for a course 45° to the primary drainage, while the tertiary streams, on side of the secondary streams, are in the right direction for a course 90° to the primary drainage. Therefore when the direction of the survey is the same as the course of the primary drainage, rely upon its valleys and divides to aid you. When the direction of the survey is at right angles to the course of the

primary drainage, the course of the tertiary drainage, on one side of each secondary drainage, is probably the same as the direction of the survey. When the direction of the survey is diagonal to the course of the primary drainage it is likely that on one side of that primary drainage a convenient secondary drainage can be found running in the direction of the survey. Its valley or divides are then to be examined. To repeat here what is written on the title page it is then always true that: "The drainage of the country is the frame work on which you must hang your located line." Obviously it is also the proper frame work on which to hang the lines which are preliminary to that location.

It is generally true that a survey which follows drainage strictly must have a circuitous route. Distance will be lost, and that desideratum of all surveys—a short line—is impossible. Practically this loss of distance is avoided by following more or less closely the drainage on the side where it flows favorably to direction and then "slashing the drainage," on the other side—i. e. crossing it at a flat angle, and crossing its divide by the aid of the tributaries of the stream "slashed." This will throw the line to one side of the straight line. Turn into direction again as soon as the controlling obstacle is passed but do not turn more, merely for the sake of getting back on the direct line. But when the next obstacle is met, turn, if possible, that side of it which will bring you nearer the direct line. To get back in the direct line merely for the sake of being there loses distance—the very thing you are fighting to save—and increases curvature, which increases train resistance and cost of maintenance. The Missouri Pacific Railroad between Ottawa and Council Grove in the State of Kansas is a case in point. The road was located generally south of the direct line between these two towns, the primary controlling points of the survey. Yet the line is not long by comparison with the air line distance between Ottawa and Council Grove.

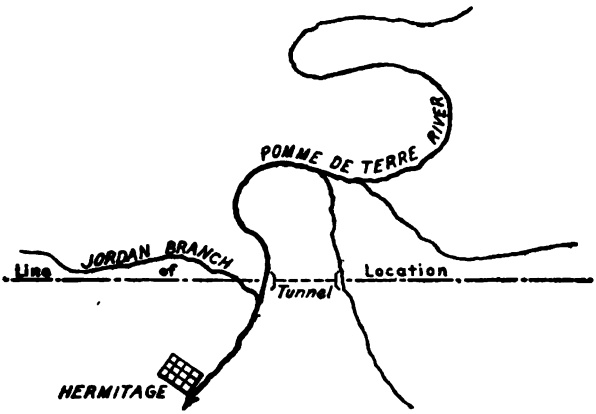

Fig. 10.

One of the early problems that confronts an engineer on reconnaissance is this question: What line is direct and short? The answer is relative. What would be a direct, short line in difficult

country would be a circuitous line in easy country. The accompanying map of the Missouri Pacific Ry. between Ottawa and Council Grove, Kansas, Plate I. may be taken as a fairly typical line of the Middle West. The average grading quantities per mile were 18,578 cu. yds. Of this about 10% was rock. The distance by air line between the termini is 66.60 miles and the length of the track is 70.37 miles. The loss in distance is therefore 5.34% of the track distance. The average curvature per mile for this line was 23° 37′; 4° curves and 66-ft. grades were used as maximums. While there is room for an honest difference of opinion, the writer considered at the time that a 5% loss in distance was not excessive for that line and has since taken that percentage of loss in distance as fairly good work in fairly good country. The located line of the Missouri Pacific Ry. from Concordia to Salina in Kansas is as crooked as any line should be in country of but moderate difficulty. There was an intermediate controlling point, however—the town of Minneapolis at the crossing of the Soloman River. The north end of the line, south from Concordia, is in rather difficult country. The Soloman and Saline Rivers, near the south end of the line cause most disturbance of direction, for it is hard to cross them but once on account of the mule shoe loops that abound. Beside this, there is much ground subject to overflow which must be avoided. This line used 4° curves and 1¼% gradients as maximums. The grading averaged about 12,600 cu. yds. per mile. The distance by the direct lines through the three primary controlling points was 50.6 miles. The distance by the survey was 54.6 miles. The loss of distance was, therefore, 7.3%. This was excessive for such light work but it was designed as an unimportant branch. To shorten this distance would have necessitated heavy work and high summits. The writer has never been obliged to lose over 10% of distance in any given line except where developing line to lose distance in order to lessen rate of grade. Distance must always be saved except where saving it costs more than it is worth. These specific cases with the percentage losses in distance are to aid engineers in forming some idea of the relative directness of their first line; in round numbers 5% for ordinary lines; 8% for branch lines; and 10% as a limit for losses of distance in the general cases. Of course no general rule is possible. State or national roads, laid out by government officials or commissions at an early date, sometimes offer a reasonable basis of comparison for justifiable length of railroad between the same points. A well located wagon road, designed to be direct will usually be somewhat shorter than the economically located railroad. Short gradients of 3% to 6% are admissible on wagon roads and occasional sharp curves are not objectionable. The wagon road laid out by state authority in 1851, from Carthage to Stockton in Missouri was 45.9 miles long while the located line of a railroad between the same points was 47.0 miles, using 1¼% gradients and 5° curves.

The question will arise: How great an angle may be turned

from a course to pass an obstacle? This query supposes that the obstacle is considerable, seems to warrant a great deflection, but that the country is quite easy. The locating engineer dislikes to see an "elbow" on a map with 10° or 15° intersections for its neighbors. The map of the Red River crossing in Texas on the Fort Worth and Denver City Railway, Fig. 15, shows the sharpest elbow the writer ever employed. The angles are over 70° at each end. The country is of but ordinary difficulty at the crossing, and generally throughout the region. Changing the hill from a 1¼% to a 1% gradient made some fairly heavy work. At no other place on the operating division had the engineer in charge of the preliminary survey used over 1% grades and obtained light grading. The Red River, Pease River and Wichita River were each primary drainage streams for that line. The direction of the line of survey was diagonal to these streams. It was necessary to turn to cross these rivers squarely or else have a skew crossing and a long bridge. We turned in each case and crossed squarely. The cross section of the stream at Red River was 1,400 ft. and very flat. The bottom was quicksand of not the worst kind. Pile trestle was used and overflow openings put in at the foot of the bluffs, as is customary. It was a crossing liable to give trouble because of the flat cross-section and character of the bottom of the stream. The Pease River crossing has given much trouble for want of a suitable overflow opening, although one end of the bridge was at a rocky bluff. Only such conditions as stated could justify such a crook in a line in ordinary country. The Red River crossing may be taken, in the writer's judgment, as the limit of crookedness in ordinary country.

Valley vs. Ridge Location.

The relation between the directions of the primary drainage in the territory between the primary controlling points A and B and the direction of a straight line drawn from A to B has an important influence on reconnaissance of route. If the primary drainage has the same course as the straight line from A to B the route would then be either a valley or a ridge location from A to B. The choice between these alternatives often rests with the locating engineer. The consequences may be considered here. A ridge route is often preferred in the middle West, as there the ridges are more frequently low and practicable than those nearer the seaboard. Among the reasons for preferring a ridge to a valley are: (1) there is little or no bridging; (2) there is no overflow; and (3) the grade lines can be kept low and quantities reduced. The disadvantages are: (1) there is more "classification" in the grading, as rock is more apt to be met on a ridge; (2) there is more curvature because a ridge is seldom as straight as a river bottom; and (3) towns are not usually found there, for towns will never incline to locate on a ridge as against a valley site. Too little weight is given to this

fact last mentioned. The road, first located in a region will often choose a ridge rather than a valley route. A second road will locate and build a line some years later through the same country and in the same direction but follow the valley no great distance from the older ridge line. The last line gets the most business. The towns were there originally and the produce comes down to the valley line rather than up to the ridge line.

While the laws of traffic are always worthy of scrutiny, and while traffic men are the safer persons to interpret them for their localities, it may be perhaps safely said that a railroad should be located like a sewer. A preliminary should be run on ground such that the traffic can flow toward the preliminary on a down grade and with no other railroad, ridge or unbridged stream intervening between the traffic and the preliminary line. Sewers are placed on lowest ground with the idea that gravity calls all fluids to it. Railroads are like placed and for reasons which seem to the writer quite similar. Commerce seeks the lines of least resistance. *Traffic is lazy and will move to the road that can be reached with least energy.*

The St. Louis and San Francisco Railroad is a ridge location to Springfield, Mo., and was located, the writer was always informed, by Gen. Fremont. There is not a town of any consequence along the line. Traffic is very meager, and could only be hauled to it up a hill at quite prohibitory cost. Nevertheless, ridge roads have always had their advocates owing to low first cost through avoidance of bridges. These lines usually have large total curvature, choppy grades, and considerable classification of grading materials.

The Fort Worth and Denver City Ry. for the first fifty miles out of Fort Worth was located and built by the writer on a ridge.[1] It now appears that the Chicago, Rock Island and Pacific Ry. parallels that line in the valley to the northwest, at less first cost, and that the "Rock Island" gets about all the business.

This means valley lines for preliminaries as against ridge lines. It means running to towns and not expecting towns to come to you. It means starting from or running to a seaport placed there by nature, or to an existing large city. It is indeed a hardy company that now hopes successfully to rival a natural harbor with an artificial one not far away. Follow the lines of commerce. Do not

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[1]The history of an error is instructive. Mr. John F. Murrell ran the first preliminary. Starting in the valley at Fort Worth, Texas, he could not find a route toward Denver. The Company in New York was in a hurry. After some delay, the Chief Engineer, Major D. W. Washburn, ordered Mr. Murrell to start on this ridge north of Fort Worth and from the track of the Missouri, Kansas and Texas Ry. When the writer was ordered to revise the location and build the road he was told by the Chief Engineer not to "waste any more time" trying to follow the valley out of Fort Worth because Mr. Murrell had tried it thoroughly and could get no line. Since then the road has changed its line and runs directly out of Fort Worth, but the unproductive ridge remains.

expect commerce to follow you. Where produce is, where manufactories are, where mines are, where storehouses exist, there you go with a preliminary. And you must get closer to the source of traffic than your rival, present or future, and do it over a length of track gradient and curvature that can never be excelled in future. Make every rival road pay more for any future advantage than that advantage will capitalize. Let others move towns, factories and grain fields. Go you to them. Be a railroad man if you ever deserve to be a locating engineer. Get all the local traffic belonging to you. Plan to hold it forever against all opponents. Then, spend all your Company can now afford to keep obstacles out of the way of through traffic.

The West Shore Railroad was ostensibly built for through traffic, and to insure low cost of handling through business at the expense of cost of construction. Granting this, the writer feels assured that *no* economic reason could have been given for that road missing Rochester some twelve miles, and Albany about fifteen miles. It is doubtful if any good economic reason could even be given for running on the north side of Syracuse so far from the center of the city. However, the writer freely admits that he believes in the value of local traffic to a line. A line should be located for both through and local traffic, giving to each its due weight.

The zone of traffic which will be tributary to a line depends upon the kind of traffic offered. This question is a most difficult one. The less valuable or the more bulky the product the narrower the zone. Prices of that product have a great influence. Transportation down stream by boat or raft is low in cost. Transportation by wagons and teams is always expensive.

In 1886 in the Saline River Valley in Kansas, it was conceded by farmers and railroads that wheat could not be grown there and handled on wagons over level roads with any profit for a distance of more than twenty miles. This, then, gave a 40-mile maximum zone for wheat at that point. If the railroad is above the level of the region adjacent the gradients of the wagon roads soon become prohibitive of traffic. What might be a forty-mile zone may then be made a ten-mile zone. A ridge between the railroad and the sources of traffic gives grades opposing that traffic. A stream between the railroad and the sources of traffic bars the flow of traffic and its bridges are throats which impede traffic's easy flow.

Among the reasons for choosing the valley lines are: (1) the line is straighter, and the curves are flat; (2) the "classification" is very slight; (3) rapidity of construction, since track layers never should catch grading forces on embankment; (4) accessibility to towns now existent and feasible natural sites for new towns, assuring favorable condition for securing the business. The disadvantages of a valley line are: (1) the bluffs to be met at the elbows of the stream; (2) the danger from erosion of the stream's bank; (3) the overflow of the valley in floods, necessitating a grade line above

high water; and (4) the excess of bridging at the secondary drainage. It often happens that the ridge route costs less than the valley route, in easy country. The effect of the location and volume of business must, however, be taken into account through capitalization and earning power of the line when constructed. In difficult country, as the existing towns are usually along the streams, the lines of reconnaissance start on a stream and it is impossible to leave the stream and climb to a ridge where the ridges are sharp combs or a series of sharp peaks.

Since traffic considerations are so largely in favor of the valley route as against a ridge route the valley route should, as a rule, be given the benefit of the doubt when the balance of desirability is not clearly in favor of the ridge route.

Crossing Drainage at Right Angles.

The primary drainage, instead of being in the direction of the line of survey, may be at right angles to it. This is the most difficult case we have to meet. The survey must pass from the levels of the different streams, which are the lowest levels of the region, to the primary ridges, which are nearly the highest points of the region to be surveyed. Not only this, but these maximum differences of elevation of that district must be overcome within the shortest distances between these largest streams. A higher maximum gradient must obviously be used, therefore, than under any other condition which concerns only the direction of the contemplated railroad and the direction of the largest rivers or streams of that region.

Passes.

The lowest saddle or pass must be found on the divide which shall be nearest to the straight line between primary controlling points. Ordinarily, this will be the first step to be taken. When the direction of the primary drainage is at right angles to the line of survey the direction of the secondary drainage is not usually with the line of survey. The probable location of the saddle or pass will be found at the head of a tertiary stream which leads up to the divide on one side, opposite to where the tertiary stream on the other side of the divide has its source, or drainage head. No such rule can be laid down for the general case, but the writer has found it saves time to expect this to be true. In country but moderately difficult the streams which head at the divide lap or dovetail by each other. That leading to the north primary drainage, for example, will head farther south than that which leads to the south primary drainage. The ridge is then a sharply zigzagged line. The head of the stronger tertiary drainage should have the shortest through cut, and the summit of the grade will be on that stronger drainage,

some distance back of the highest point on the ground line of the profile. When the drainage areas lap by each other alternately at the divide the quickest way to find the place to cross that divide is by riding along the divide.

When the streams at the ridge leading each way towards the primary drainage neither abut against each other nor lap by each other the divide is a very high steep one or a broad, low one. If the former, a pass will have to be found. If the latter, a stream should be looked for penetrating with its head waters far into the divide, and if possible, on the side of steepest ascent from the primary drainage to that divide.

A very valuable pass in the broadest sense is a geologic *fault*. The ordinary pass or gap results usually from a stronger earlier stream which began by flowing across the divide before the sides of the divide were made by erosion. Softer rock or drift material may exist there to aid the erosion of the young stream. Not infrequently, a pigmy stream now flowing from the gap is running in the reverse direction from the stream which originally existed, whose work it was to cut out the gap through the divide.

Passes are found only by close search. Some of those now historic have been passed again and again by locating engineers. When the divide is so broad that streams do not abut closely to each other nor lap by, and the country is not rugged enough to give reasonable hope for a gap or pass, we have the general case of a broad, comparatively low ridge. When this ridge is too steep for the maximum gradient to ascend there is no recourse but to lose distance, that is, to *develop* the line so as to increase the distance on the ascent sufficiently to enable the maximum gradient to carry the line over at the developed distance. Piling up curvature on a straight line is one thing; developing a line is another thing. Make up your mind which one to try in that locality, and try it all the way up. There may be ground not far away well adapted to the other method of climbing to the same divide. Then you have alternative routes, each with the method best adapted to it. These when surveyed give a fair test of method, and such a course of preliminary study for located line commends itself. Developing will be considered in a subsequent paragraph.

When a developed line cannot be found which is sufficient to carry the railway over the divide, or no gap exists low enough to let the line through, a tunnel must be resorted to under the crest of the summit. The narrowest point in the crest of the divide must be found, preference being given to a locality where rock exists for a roof. It is to be expected that considerable deflection from the straight line will be necessary.

In the general case we are now considering where the primary drainage runs squarely across the direction of the line of survey, it frequently occurs that a tunnel a few hundred feet long is ad-

visable just after crossing the primary drainage in order to reach the valley of the secondary stream through the sharp ridge that separates the two streams. It often happens in difficult country that the secondary stream runs almost parallel with the primary one, and it may be quite close to it for some distance before it empties into the primary stream.

Crossing Drainage Diagonally.

We have seen that where the primary drainage is parallel to the line of survey easy work was ordinarily met, and that we could choose between a valley or a ridge route. We have also seen that where the primary drainage was at right angles to the direction of the line of survey the maximum gradient was taxed and a costly line ensued. We are now to consider the general case where the primary drainage is neither parallel to nor at right angles with the direction of the line of survey drawn from one primary controlling point to the next. This angular direction of the drainage is most promising in choice of experiments for passing through the region with a railway. For, if the country be difficult, under the limitation of gradient and curvature given in instructions a primary drainage can be followed for a distance to where easier country offers, without turning at right angles to the proper course. While this is seldom necessary, it is often desirable to follow secondary, tertiary or quaternary drainage which this general case allows at once. The direction of the drainage here offers the most promising "framework" on which to hang the located line.

The angle which one stream makes with another stream into which it empties is of course not to be predicted, because topography follows too complex laws. The upstream angle along the primary drainage is of course less rather than greater than a right angle. A tertiary drainage is somewhere nearly at right angles in direction of the primary drainage, and the quaternary drainage occupies about the same relation in direction to the secondary drainage. These expectations involve no general law, but have some foundation in usual experience. The angles which a valley makes with the valleys of its tributaries continue about the same through some distance of its length. The writer always expects to find tributary streams at a sharper angle with their primary streams, in difficult than in easy country. It is best, while knowing that no general law can be followed, to consider it possible to predict local conditions with sufficient accuracy to aid reconnaissance. After riding for a few days in reconnaissance in a certain region one should make better progress because of having learned what to expect. We have assumed thus far in our reconnaissance for route that a line could be found within the limits of curvature and maximum gradient given in the instructions. Unfortunately this is not always the case in practice. We have spoken of tunnels, and they may be used at a summit too high

for the maximum grade to surmount, as well as in sharp ridges at various other localities. We must now consider the methods which may be employed in surmounting a hill which is too high for the maximum gradient to carry the line over by ordinary methods. We shall consider these methods in the order of their desirability for operation.

CAÑONS.

A deep cañon[1] which has few sharp crooks, and sides of material hard enough to stand at a steep slope may afford a short and easy line to operate, though a costly line to construct. The *mesa* at the lower end of the cañon, in which the walls of the cañon are cut, must have a quite easy approach, so that the line can start up the cañon on the top of one of the side walls. As the line climbs towards the summit it must descend toward the floor of the cañon, since that floor is rising at a rate greater than the maximum gradient. Were the gradient of the floor of the cañon not in excess of the maximum gradient the line could, of course, be located in the cañon itself, and this would be no case of special difficulty. As the line reaches the summit if it touches the bottom of the cañon before it reaches the crest of the hill there must be a through cut or a tunnel.

When there is a broad divide to cross, the cañon to be sought on the flat side of that divide is a cañon that is long and on one side of which the slope is flatter than the angle of repose for the material there.

Great width is not needed and a narrow cañon is even desirable for this purpose because the more available side may change so as to make it best to cross the cañon when part way up to the divide. On the contrary for a developed line the slopes of the sides may be of any angle and the cañon may be very crooked, but it must be wide and have a quite level floor. The choice of cañons or long tertiary streams is not an easy one to make. The grade of the floor of the cañon or the bed of the stream as compared with the maximum grade of the line must largely influence the choice. One side of the divide is ordinarily steeper than the other side. Seek, therefore, some drainage on the flat side, either secondary or tertiary which is best for direction and heads back in the ridge the farthest. Follow that drainage to the summit of the divide, putting in the summit "cut" at the head or back of it. Then use a developed line on the steep side of the divide, giving the line plenty of length between the turns. Short zigzags give great curvature per mile, and when that curvature is equated for much of the benefit of the development is lost.

[1] A true cañon has vertical sides. The term cañon is here applied to streams whose sides are very steep but not necessarily vertical.

DEVELOPING.

The idea that development of line can be resorted to anywhere is a mistake. Great care and judgment are needed in selecting the country on reconnaissance for developed lines. Much lateral room is needed. While a smooth, even slope would seem the ideal ground, broken country whose general slope is suitable seems to have greater adaptability. Apparently bad country has given developed lines which are all that could be desired in gradients and curvature, while the "grading" averaged very light. The writer has felt in his own work that it was best to find ground for a straight climb, but if that did not suffice, then ground must be found over which to develop a line by broad lateral development. Zigzagging about on the more difficult portions of a hill, where straight running is sufficient for most of the climb, is seldom good location work.

Developing a line consists in adding to its length in order to surmount a summit without exceeding the maximum gradient allowable. In developing a valley first find the slope of the valley at that point of its course, usually within the middle half, where a certain slope continues for the greatest distance. This rate of slope must not exceed the maximum gradient of the line.[1] Learn whether there are any great obstacles to prevent reaching this portion of the bed of the stream or valley from below. As the stream ordinarily has less fall in its lower portion, there should be no serious difficulty in reaching the middle half of its course from below. Follow then, with a reconnaissance this stream throughout its middle half, planning to locate the line safely above high water, but using the maximum gradient unless the ground will not economically support it. When the valley toward its upper portion along the stream rises too rapidly for the maximum gradient and the summit is still some distance away, a resort to development of line is necessary. Inasmuch as development of line is contemplated, the stream selected must have a broad flat valley or run in a very broad cañon with a level floor. The reason for this lies in the fact that a developed line requires lateral space to prevent large increase in total curvature on the ascent. This curvature must be compensated or equated for and such compensation defeats the very object of development, namely, ascending without advancing. A zigzag development is the easiest development for which to find a route. This resembles in plan what is popularly known as the Virginia rail fence. The tangents are about an angle of 45° with the general course of the line, and there is about 90° in each curve. Obviously,

[1] The Texas & Pacific grade from Rio Grande Valley, below El Paso, Texas, to Sierra Blanca, is a case of this kind. The author's recollection is that there is no curve sharper than 3°. The ascent to the *mesa* was gradual. There was no summit "cut." The line is short, but the grading was heavy for four miles.

this method of climbing an ascent does not demand a straight valley or cañon, as does the one just considered.[1] A line developed by zigzagging, with its tangents at about 45° angles to the general direction of the ascent theoretically increases the distance through development 41%. This uses 90° intersections for tangents. When the curves are run in on 90° intersection the shortening of line which results is considerable. Unless there be a great deal of lateral room and long tangents made possible between these 90° intersections the increase of distance will be nearer 25% than 41%. Therefore, when increasing the distance 25% is not sufficient to carry the line to the summit with the maximum gradient permissible, more than 90° must be tried at the intersection. This gives us a "horse shoe," or if still greater angle be used a "mule shoe" curve, as they are called. Ordinarily the line has climbed well out of the initial cañon or valley and is well up the mountain side before "mule shoe" curves are needed. Plenty of lateral room must exist to make them possible, and broken ground on the steep general slope seems best adapted to their application. A mule shoe curve has over 180° of total (external) intersection angle, and the entire series of curve is without a tangent. Ambitious passenger departments frequently advertise mule shoe curves as "loops" and say the advancing train reaches a point "within a biscuit toss" of the track it had recently passed over. The term "loop" is not applied to these zigzag, horse-shoe, or mule-shoe curves, and must be reserved for the next method of development, where these curves already considered cannot give a sufficient development. A fine example of this kind of developed line may be seen on the Southern Pacific Railway system between Sacramento and Portland. The line was located by Mr. William Hood, now Chief Engineer of the road. The location was made expeditiously through difficult and rough country. At one point the line is tunneled under itself, thus narrowly escaping a loop. As a developed line that location will repay study. On an obscure railroad in Chili, South America, between the towns of Ovalle and San Marcos, there is a good specimen of development of lines. The location was made long ago by a Mr. Douglas, an Englishman. The ground is well chosen. The location is fitted to the ground. A considerable increase in length is developed. Said the locomotive engineer to the writer, as they reached the summit: "The train pulls just the same all the way up." What better monument for a locating engineer?

One of the difficulties in reconnaissance for route where con-

[1]The location of the Southern Pacific Ry. east of El Paso from the Valley of the Rio Grande River to the summit at Sierra Blanca is a case in point. At the lower portion the location shows a developed line by zigzagging in a broad cañon having a level floor. Farther along and as you approach the summit of the Sierra Blanca hill the vertical sides of the cañon cease, the ground is broken by small hills and ridges, and the development is more in the nature of horse-shoe curves.

siderable development is needed lies in the fact that the air-line distance from the valley to the summit has lost its value. It is itself the obstacle you seek to overcome by making it greater. Where horse-shoe or mule-shoe curves are necessary, the reconnaissance for route cannot be by courses and angles by prismatic compass and paced or timed distances along straight reconnaissance lines. For this problem the aneroid or cistern barometer, when it has shown satisfactorily the difference in height between the valley and the summit, has completed its work. When the air line distance from the valley to the summit is learned through timing the horse several times over the line or by the use of an odometer, and the lateral distance available at all points is learned, the horse has completed his part of this work. If the development covers no considerable area the locating engineer with a prismatic compass and a hand level can develop the line on foot, taking such notes as will assure him how many swings must be used, how long they must be and how much total angle for each. He must step the distances, noting the course and using small natural objects for turning points of the hand level work. It is much better to have a rodman to assist. The engineer must rely on repetition to check the work, and before going over the developed line the second time he should plot to scale his reconnaissance line, making maximum cuts and fills as well as courses and distances. On the second or check running he marks on the map, or records his various directions. Should this development of line cover considerable area a level rodman is indispensable. A self-reading rod will serve and can be made for the purpose. Should the locating engineer be unaccompanied by guide or driver any handy man can use the rod. The driver, if used, should be able to read a rod, which should be a short sliding rod. A stadia instrument is not yet necessary, but may immediately precede the preliminary line. Since you cannot get the developed distance accurately on reconnaissance there is no need of getting the difference in levels accurately. The reconnaissance must show approximate differences in levels of the top and bottom of the hill and length of line to enable the maximum gradient to reach the summit, plus an additional distance between valley and summit sufficient to cover the shortening of the distance due to curves.

Loops.

When methods stated thus far are inadequate to passing over the summit with the allowed maximum gradient, the next recourse in order of natural sequence is the use of a loop. By this is meant the crossing of a line by itself for the purpose of gaining elevation at the point of crossing without in the least advancing towards the summit. The difference in the elevation of the upper and lower tracks at the crossing represents a virtual reduction of the summit by that amount. Loops are usually classed as *bridge loops* and

tunnel loops. This designation indicates whether a bridge or a tunnel is the means of passing one track under or over the other, and has no signification concerning the character of the loop itself. A prominent instance of a bridge loop in this country is the so-called Georgetown Loop on a line of the Colorado and Southern Railway of the Union Pacific system, between Georgetown and Silver Plume, Colorado. Through the courtesy of Mr. Herbert W. Cowan, Chief Engineer of the Colorado and Southern Railway, we are able to show here the map and profile of this famous loop (Plate 3). It was a branch line ending at Georgetown. At Silver Plume were valuable mines close up to the crest of the Rocky Mountains and at some 600 ft. greater elevation than Georgetown. A direct line would have necessitated an 8% gradient. Using the bridge loop and the considerable development above the loop towards Silver Plume, a 3.6% maximum was obtained. The location of the line before the first crossing of the creek was reached and below where the line is shown here is a good instance of following up a creek until its bed is no longer below the grade line, and then resorting to the next device which the lay of the ground suggests, viz., turning down stream on an ascending maximum gradient.[1]

A prominent instance of a tunnel loop is the Tehachapi Loop, on the Southern Pacific Railway, north of Mojave in California (Plate 2). This was, so far as the writer knows, the first loop located in America. It was located in 1875, by Mr. William Hood, now Chief Engineer of the Southern Pacific Ry. The idea, as we have said, was original with Mr. Hood at the time, as he had never seen or heard of a loop in railway location. On the St. Gothard Railway in Switzerland and Italy there occur five tunnel loops, together with other types of developments. Some of these loops are almost entirely in tunnel. The line was located only after exhaustive study. The maximum grade or tangent used was 2.6%, and in the judgment of the engineers in charge represented the economic maximum grade for engine tires on smooth rails there.

When a loop crosses a line more than once it might be called a spiral, but the terms loop and spiral are used interchangeably. It cannot safely be said that a loop is an entirely distinct method of ascent. It is more correctly a "mule-shoe" curve applied where the topography points to the economy of extending the curve on the returning portion until it crosses the line at the beginning portion of the same curve. A loop is possible economically only where the topography indicates its advisability. On "scenic routes" for tourist passenger traffic mainly a loop adds a certain value to the property. Loops are interesting to all, and will not be so numerous in the future that they will cease to be novel. They represent the

[1]This loop was located under the supervision of Mr. Blickensderfer, then Chief Engineer of the Union Pacific Railway, which owned this line. The construction was in charge of F. A. Maxwell, C. E., of Georgetown.

extreme device for development of line without changing the direction of the train and running it backward.

Tunneling.

A summit tunnel is a confession of the inadequacy of development of line for that locality. The length of the tunnel and not the distance from ground to grade is important, while in a through cut both length and depth are important. A knife edge summit is what is desired for a tunnel location, of course. Strong streams which abut at their sources are most apt to furnish a knife edge on a divide. Even more important than shortness of tunnel is the roof available for the tunnel section and the material to be removed from that tunnel section.

He who has read "Tunneling," by Mr. Henry S. Drinker, will recall the record of difficulties at the Musconetcong tunnel on the Camden and Amboy R. R. (Lehigh Valley Railway), when "it seemed that all Jersey was flowing towards the tunnel." Mr. Drinker, who was an assistant to the engineer in charge of the construction, referred to the large quantity of water that was met. It was believed to be a subterranean reservoir. A wet tunnel site with soft ground will usually make the tunnel expensive and the date of completion uncertain.

A stout ledge of rock for a roof, a material in the cross section which excavates well and requires no side walls, freedom from water and a knife edge divide giving minimum length for a maximum summit passed through are the important considerations in the selection of a tunnel site.

A considerable change in the rate of gradient within the tunnel is not desirable for operating reasons. Trains are apt to break in two by reason of wide variations in draw-bar pull in passing these marked changes in grade which the locomotive engineer can feel rather than see. Short tunnels should be so located that there should be no change in rate of grade within them. Long tunnels should have grade lines connected by such long vertical curves that the change in rate of grade would be imperceptible to the locomotive engineer, and therefore not likely to break couplings by sudden demands upon the engine. Naturally, a long summit tunnel changes from ascending to descending grade near the middle of the tunnel. A very long vertical curve should be used. In this case the drainage is both ways from the center, and therefore most desirable. A curve in the alinement within a tunnel, unless it be so sharp that it tends to increase train resistance or be dangerous at train speeds, is not the obstacle it once was. We feared them because there was danger of the transit line not meeting as extended from the headings. In recent years, instruments and implements of survey are so improved that center line checking gives little anxiety. The time has passed when the engineer by "splitting the tack" in joining heading lines had reached the height of tunnel engineering work. How to drive the "heading" and take out the

"bench" under the myriad conditions nature affords, and do it rapidly and economically, is a problem much more worthy the engineer's skill. Improved machinery and high power explosives have made tunnels less expensive than formerly, and they will probably be built oftener in the future.

Switchbacks.

When development of line on compensated curvature has failed as a means of climbing to a summit, either by the usual locomotive or by increasing its weight, or by the use of assistant engines, the line can be one of limited capacity only. The gradient has practically or quite passed the working limit of adhesion of an engine's tire on a smooth rail. Such cases occur, however. When the road engine cannot accompany the train or a passenger train must be divided into sections, the delays and increase of cost of operation must be considered a great barrier to traffic. There are at least three methods remaining for surmounting the summit: (1) switchbacks; (2) inclines; and (3) rack rails.

A switchback[1] is one of the earliest devices used in places of special difficulty. When trains were light and infrequent switchbacks were quite adequate. The Delaware, Lackawanna & Western Railway is now operating the extremity of a branch line into Ithaca, N. Y., on the switchback method. Did the volume of traffic warrant, they would no doubt relocate the line and use an ordinary development for the ascent. The most historic of these roads in the United States is the Mauch Chunk Switchback, built prior to tractive power railroads in that part of Pennsylvania. The road was built in 1827, to take coal from mines to a canal. It is now operated for its scenic attractions. The famous Oroya Railroad in Peru employs the switchback principle. A common use of the switchback is for a temporary line over a high elevation to be used until such time as a tunnel can be conveniently built. An excellent example of this is the switchback used on the Great Pass in the Cascade Range. The developed line exceeds the Northern Railway in the State of Washington through Stevens straight line by ten miles in length, while advancing about two miles in distance. A tunnel has since been built, and is now in operation, as shown in Plate 4.

The ground favorable to their use is not unlike that most favorable to zigzag development, but can be steeper in its slope. The rate of grade must be reduced near the switches, and the stems or legs must have a quite steep ascent from the switch, and may have considerable curvature. The engine should need no steam in descending, as by so doing the length of the switchback will consequently be longer. The gradient should be adjusted by practicable velocity heads, so that the vertical profile is economical.

[1] A switchback consists of one or more sharp zigzags in the track, with a switch at each of the changes in direction.

The grades against the traffic should be those of a mineral road for slow trains, and these grades must be eased off at the switches.

A switchback is economical for slow traffic of no considerable volume. We must not forget that it is slow, of small traffic capacity, dangerous at the stems or legs of tracks beyond each switch, and last, but not least, the train must run backward over one-half of the ascent. This adds to dangers of operating and makes slower speeds necessary.

Inclines.

An inclined plane, sometimes called an "incline," offers a quick solution to the problem of ascent which baffles traction.[1] By using a stationary engine and cable of sufficient strength it is possible to haul up a train quickly and with a short length of track. Since the motive power is not a heavy engine which must also lift itself up the height as well as lift the train, the stationary engine is economic of energy. If the incline be double track, as it would need to be on any considerable traffic, a descending train can often aid, at least, in pulling up an ascending train. It was originally supposed that inclines must be straight in order to use cables (then of manila). Street car development has shown us that cables can be used around curvature safely if not economically. The objections that can truly be urged against inclines are that they usually contemplate breaking trains into sections, that they fix an end of division at what may not be an economic distance and that they consume time. To the writer it seems impracticable to consider inclines for aught but lines of light freight traffic. Time is too valuable an element in railroad transportation to consider inclines for other conditions than the one named. It is idle to speak of inclines on a passenger line, when passengers have an alternative of going by some other route or even not going at all. Time freight will shun inclines. For a purely freight road, having low class freight only, an incline may be advantageously used.

A rack rail[2] is another device for unavoidable high gradients. While there are different systems, the one designed by Abt and known as the Abt system is most common. It consists of a toothed rail between the ordinary rails with a gear wheel running in it. To this gear wheel the motive power is applied. The steam power is not dependent on the friction on the smooth rails or the weight of the engine on the drivers for tractive power. This last fact gives great economy and makes very steep gradients practicable. The

[1]Inclines are still used on the Switchback Railroad at Mauch Chunk, cited above. The switchback of the D., L. & W. R. R. at Ithaca was originally an incline. They were used on the old Portage R. R. to carry canal boats over the Alleghany Mountains in Pennsylvania. It is said that the Pennsylvania R. R., when located, contemplated the use of inclines when the traffic was heavy enough to warrant their use. Probably when the traffic was heavy enough inclines were considered too slow.

[2]See Trans. A. S. C. E., 1886. Article by W. W. Evans.

rack line method resembles the inclined plane in its traffic effects, but is best adapted to a higher traffic which is to be hauled for a greater distance and ascent.

FIELD NOTES.

The following are the reconnaissance notes for preliminary line on the first portion of a 125-mile reconnaissance: "June 1, 1888, J. C. & S. W. R. R. of the Mo. Pac. System. Reconnaissance for preliminary N. E. from Carthage, Mo., Jasper and Barton counties. Leave the track of the Lexington & Southern R. R. in Jasper Co., Mo., north of the Carthage depot at the top of the first hill. It is on what is known as the "Senate" farm. Start 500 ft. north of that summit on the track and turn 46° 15′ R. and to the N. E. Try for a tangent to Golden City which will leave that village close to Rt. of line. This tangent should give a good crossing of Buck Branch ¼ mile W. of Pleasant Dale School House. It will run close to Mayflower School House, after crossing Dry Fork of Spring River high on north side of that stream. It will probably cross Coon Creek fairly well. On the right of the line south of this creek the high grounds should be "hugged." We must cross on the high ground and run for the lowest point on ridge N. E. This is the hardest to climb on this tangent, and is just north of the north line of Jasper Co. This tangent leaves Jasper Co. a short ¼ mile east of the N. E. corner of Sec. 18 on the Peter V. Shell farm. In Barton Co. the tangent continued should keep Wyatts Creek to the right and get low in it to save gradient on the K. C. Crossing (K. C., Ft. S. & G. Ry.). Turn opposite or near Golden City so as to cross the track W. of the west H. B. (Head Block). Tangent ends at this Golden City curve. Lay the next tangent to cross Muddy Creek on the Widow Smith's farm ⅛ mile W. of Co. line. Leave Barton Co. on this tangent on the Widow Smith's farm from ¼ mile S. of N. E. Cor. Sec. 23."

These are the actual notes. The first tangent tried for was about 17 miles long. In such settled fenced countries one cannot ride along the tangent on a horse but must "zigzag" the line by the wagon road. To walk over the country for that distance takes too much time. Land maps and surveys have errors especially at townships and county lines. One cannot be sure within 1,000 feet of where that tangent would land. It is best to run as near the direction as you can determine, noting the ground needed. These notes tell where the line should be, in the judgment of the chief of party, and where the difficult part of the line is. The preliminary topography must especially take notice of these points. This tangent as now recollected was on location "pivoted" about a point towards its initial end—i. e., the located tangent there crossed the preliminary one. The maximum change was not many hundred feet. Since this part of the J. C. & S. W. Ry. was the easy part of a difficult line in the Ozark Mts., direction and not elevation governed.

REPORT OF ENGINEER.

Having now concluded the reconnaissance for route beginning at the initial point and closing at the terminal point laid down in the letter of instructions from the chief engineer, the locating engineer makes a report which may be read as follows: "I find a route practicable for the maximum gradient mentioned in my instructions, and for the maximum degree of curvature except at the crossing of the ——— River where the maximum degree of curve must be increased but will not exceed safe operating limits. The length of the line is about 125 miles, and will vary 3% as a maximum either way from the estimate length. The grading will average 18,000 cubic yards per mile. This amount may be increased 1,000 cubic yards or decreased 2,000 cubic yards per mile. The earth is a sandy loam. The amount of solid rock will be light, but there will be considerable material in cuts at the beginning of the line which will probably require loose rock classification. 75,000 cubic yards for the whole line will be an outside estimate for this loose rock. A short tunnel in dry rock furnishing a good roof will be economical at the point of crossing the main water shed. It is limestone rock in heavy ledges and not hard to drill. This grading estimate contemplates that the tunnel excavation to be added will be for a tunnel length of 500 ft. Timber clearing will be for one-half the distance. There will be required about 130 ft. of pile or trestle bridging per mile. In addition there will be needed three 75 ft., two 100 ft. and two 150 ft. truss bridges. Masonry is not contemplated in construction. It is recommended that of the two courses to pursue at D, as per instructions, the line should leave D over five miles to one side. The rate of maximum grade must be increased to pass through D. Inasmuch as we pass through E a town of quite good size for the best and most direct route, it is recommended that a branch line may in future be desirable from E to D. This would be seven miles long on moderate gradients. It is probable that water stations can be located safely at the three rivers. Beside the increase to side tracks at A there will be required eight miles of sidings and twenty switches. Probably one first-class, two second-class and five third-class depots will be required."

CHAPTER III.

Organization, Subsistence and Equipment of Parties.

"The most difficult and at the same time the most important branch of engineering is the engineering of men."—Robert Stephenson.

The personnel of a field party for railway location varies with the conditions. If we assume a field party for prairie country, living in camp, we have a fair average party. To this party axmen must be added, if in heavy timber, and teamsters if the haul of supplies is long. From this party a cook and some teamsters must be taken if the party is quartered in towns or among inhabitants of the region. The men usually needed on a camping party in prairie work are sixteen in numbers, as follows: Chief of party, Assistant, Transitman, Draftsman, Levelman, Head Chainman, Level Rodman, Rear Chainman, three Axmen, Rear Flagman, three Teamsters and Cook. Since there are no substitutes, and the work is hard and the exposure severe, these should be picked men. Each man must be able to do his work easily and promptly. He must have experience and speed. He should not need to hurry nor to be fatigued after doing his work. Since the men live together in camp in close quarters it is imperative that all be good tempered. An ill-tempered man cannot be economically used. If he be the best engineer in the party, bad temper makes him worthless for a locating party in camp. There are few places where a good disposition is so invaluable. To this end drinking must be prohibited. Gambling and the reading of poor literature are also sure to cause trouble.

Nor is it enough to have good men. They must be well handled. An engineer who shows that he is a poor chief of party by failing in his handling of the men of his party will never be an economical engineer for a party living in camp. Engineers must know that men are human, and not equations, if they expect to locate railroad economically and well. As an American soldier differs from a Hessian, so does a man on a locating party differ from a man on other work. The golden rule is the only basis for their treatment by the chief of party. A party is a social democracy, but the discipline should be rigid. These men do not care, as a rule, how hard they work or how severe the exposure if they are "treated right." They expect the chief of party to be a despot. Some one has said that "A despotism is the best form of government—provided you have the right fellow for despot."

There is in this country the very finest material from which to recruit men to be trained into good locating parties. They are

found among guides in the West, teamsters in freight outfits, prospectors, cowboys and ex-soldiers of our regular army. These men have initiative, are self-reliant and used to the life. Among these men find a man who was brought up in a timbered country, especially Canada or the mountains of Virginia and Tennessee, and you have the ideal axman. Among them find a man accustomed to horses when a boy, one who has handled teams for the Government, for freighters or for railroad contractors, and you have an ideal teamster. This principle of natural selection applies to the engineers of the party. They must have been long used to hard work. The discipline, the "team work" and the ability to take punishment that may be learned on a university boat crew or football team are advantageous. Ex-soldiers, guides, cowboys and college athletes can together make a strong party.

We shall now give in detail the duties of each of these men and the qualities each needs for his work. The following is based upon the writer's experience with men under widely diverse conditions. The men are mentioned in the order of their rank and their rate of pay. There should never be ground for debate whether one of two men outranks the other. When the duty and the pay are the same, seniority of service gives rank.

CHIEF OF PARTY.

The Chief of Party may have the duties of Locating Engineer of the road. We shall assume that he does not, but that he reports to the locating engineer who has previously made the reconnaissance for route, and has then sent out the party under this chief of party to run the line or lines. Since the locating engineer has himself made the reconnaissance for route, the chief of party will of course have the benefit of the locating engineer's explorations, and judgment, and be given a copy of all the notes of that reconnaissance. The chief of party must at least be so capable in reconnaissance that he can take this information, given him by the locating engineer and intelligently use it. His first work is what is called *reconnaissance of line*. It is the most vital part of the work of a chief of party. His field work will be spoken of at greater length under the head of preliminary lines, and his equipment and instruments will be discussed in their proper place later in this chapter. He has absolute charge of his party, under the locating engineer, and may hire, fix, increase or decrease salaries, and suspend or discharge the men. The more isolated an organization the more despotic must be its control. For this reason a chief of party must be fit to have this sweeping discretionary power. He can be no inexperienced or immature man, or the best of organizations will speedily become demoralized. The reason for giving him the right to fix the rates of pay, under advice of the locating engineer, is that the best test of his economical work is the cost per mile of fit preliminary or of acceptable

located line for that region. Amount of payroll or monthly cost of subsistence is not a proper criterion. A man experienced enough for chief of party will be most economical in a true sense when judged entirely by results—cost per mile of good work. That criterion alone can put men to their best efforts. The chief of party should assign to each man of the party the explicit duties required of him. Each man should be held responsible directly to the chief of party for the way in which he performs these duties. Never "farm out" responsibilities, or have some man who "helps" another man. Never pay one man for urging on another man. Hire men who will do their duty, behind a good and wise pacemaker, without urging. Of course the chief of party must hold each instrument man responsible for the quality and quantity of his work, his records and the condition of his instrument. The same conditions apply to all the men of the party.

As the chief of party will be held responsible for disbursements he is therefore the steward. The supplies must naturally be attended to by the boss teamster and cook, but for this very important part of the work in a camping party the chief of party is properly held directly responsible to his employers and also to his employees. A chief of party who does not know how to take charge of the subsistence of men and teams should not work a camping party. Be he the finest of locating engineers, he will surely fail.

While performing the duties of scout, quartermaster and commissary, day by day, he must make complete reconnaissance of the country for line. This is his major duty. Each night he must lay the grade line on the profile of the day's work of the party, plat the transit line to be, and give a full topographical sketch with "horizons" to the assistant and topographer by which to find the route of the line for the next day's work. Of these strictly engineering duties of the chief of party, more will be said in the next chapter.

Concerning the preliminary training for the chief of party the following may be said: He must at least have had good experience in level and transit use. Nothing trains the eye better for judging rates of slopes of ground than running a level. Angles are more visible in a reconnaissance to an old transit man than to one who never stood behind that instrument month after month. Some of our best chiefs of locating parties have attributed their success chiefly to the fact that they were previously good topographers. Drainage[1] may be considered the framework of topography. By being a topographer we do not mean having the ability to make fine topographical notes, but rather to photograph a map of the country upon one's brain—a map which can be seen correctly for some time afterwards by merely closing the eyes. There are

[1]"Drainage, *drainage*, DRAINAGE! If you cannot get the idea of drainage in your head you may as well hang up your fiddle as a locating engineer," said the late D. W. Washburn to the writer when starting him to locate the first part of the Ft. Worth & Denver Ry.

those who could not pass an examination as a topographer, yet are good chiefs of party. "Eye for country," as it is called by some, seems to be this broader topographical faculty more or less natural to the individual.

A chief of party must have had experience on construction. He must run preliminary lines for a time before attempting located line. He should have seen service on maintenance of way before locating a railroad. If he has not had such broad experience, then the locating engineer must be one of such experience and give some attention to the final line before its adoption. A locomotive and its performances give to a locating engineer certain schooling no transit or level can, and it can be met only on maintenance of way.

THE TOPOGRAPHER.

It is best that the Topographer be the man to have charge under the chief of party of the line party during the day. Often the transitman is given charge, and an assistant is given to the transitman who really runs the transit. The transitman can then take the topography and pick out the route from the topographic sketch furnished by the chief of party for that day's work. But since two men are needed to do the entire work of running the transit, taking the topography and keeping the party in the route, it is better to have a transitman to run that instrument only, and let the topography and route be looked after by the other man. As the topographer is not confined to an instrument he can more readily go forward, as sometimes becomes necessary to determine the correct direction for the line. So arranging this portion of the work makes it necessary to provide suitable men for these two positions. As the topographer has charge of the line party during the day and ranks next the chief of party at all times, we shall call him the Assistant. He must take all topography needed for location. He must be able each day to find the route indicated by a sketch of the chief of party. This sketch must be topographic in all its connections, because one man must make and another man use it. If the assistant be an indifferent topographer he cannot find his route from the sketch. The transitman follows the assistant's line as directed from point to point, and the assistant keeps up, as a rule, with the head chainman, or slightly ahead, during the day. He indicates where transit points must be taken for angles. He does not give heed to transit or level work or chaining. He does not prompt or urge on any of the men. The men are each instructed by the chief of party in their duties, and directed that in emergencies or special cases the orders of the assistant, however unreasonable they may seem, are to be implicity obeyed at once, and without comment. At night they are to report grievances to the chief of party, whose duty it is to attend to discipline. Controversy is thus made impossible in the field, and friction and time saved. This reduces the ordinary duties of the assistant to finding the route and to taking topography.

The professional qualities of a good assistant are an aptness for topography added to considerable general experience in railroad engineering. He must have served in the lower capacities of transitman, draftsman, and levelman so as to be able to advise them when asked in an emergency and give them their "breaking in" if they are new to their work. As the assistant, as well as the chief of party, takes note of ditches needed, size of openings and "classification,"[1] he needs to have had long experience in construction work. An assistant on a located line should be a man qualified to be chief of party on a preliminary in ordinary country after a locating engineer has made the reconnaissance for route. He should be in the line of promotion as chief of party. His personal and executive qualities naturally suggest themselves from the character of his duties. He should be experienced in doing railroad surveying and in handling field parties. He must not be timid nor careless, nor "finical." He must treat men well, expect good work of them and leave them alone to do it.

THE TRANSITMAN.

The third man in rank is the Transitman. It is his duty to run the transit, keep the alinement notes and at night assist in platting his transit line. He must, of course, adjust and maintain the transit in perfect order. As he carries the heaviest instrument, and so many men await his walking forward and setting up of instrument, it is economy to spare him all the work possible. Men of the line party should help him over fences and in setting up. Platting his transit line in pencil, or checking that work as done by the draftsman, is all the office work he should do at night. A tired transitman is uneconomical.

Before a man is capable of running a transit economically he must first run a level. Otherwise he will waste too much time setting up, and each minute is a minute for each man of the party. There are plenty of good engineers who are not good transitmen because they need too much time in setting up on rough ground or in high winds. A transitman must be, or must soon become, a first-class and ready instrumentman, or the company cannot afford to retain him. He should be able to use either eye in sighting, and his eyes need to be strong. Of course the telescope remedies any deficiency in focus of his eyes. He must be an accurate, conscientious man who can be relied upon to do excellent work without wasting time. Between culpable carelessness and foolish hair-splitting there is a golden mean of rational accuracy. We no more need coast survey refinements in centering and sighting on railroad location than we can allow the inaccuracies of compass surveying. As the work of a transitman is heavy, and very confining he must have good health and strength.

[1]Noting whether material be other than "earth," i. e., loose rock, solid rock, etc.

THE DRAFTSMAN.

The Draftsman should have had experience in railroad mapping. It is well if he has run the level on location. He need not be a draftsman capable of finely executed work but he must be accurate and have plenty of speed. His knowledge of trigonometry must be good. He needs to be able to do reliable work, acceptably executed, and do this with meager appliances under annoying conditions.

THE LEVELMAN.

The Levelman, besides running his instrument, keeping it in adjustment and taking level notes, should take notes to supplement and to check the assistant. These notes should embrace rock outcrops, changes in material to be met in grading, widths of water channels, sizes of proposed openings, and show where clearing of "right of way"[1] of road must begin and end. He must adjust and maintain in good order his level. His office work consists in platting the ground line of the profile each night, the rodman calling off the level notes. As the use of the level demands less professional experience or aptness than the transit this position may be filled by some young graduate engineer or by a man who has served in lower grades of engineering service and has been a rodman for a considerable time. A young graduate engineer who serves a few months' apprenticeship with a level rod under an excellent levelman makes the best levelman at the start. Whether a rodman or a student be the better material depends on personal qualities of the two men compared. The student will not get on as well as an old rodman for the first few weeks, but will do better after the first few months, and stand promotion better, a desirable quality in all men. It is sad to see a man, who has served in engineering parties for a long term of years, unable to attain a higher rank than levelman because of his lack of knowledge of mathematics.

THE HEAD CHAINMAN.

The first duty of the Head Chainman is that of pacemaker for the party. The pace must be accommodated to the strength and duty of the weakest member of the party. As conditions change, the chief of party upon conferring with the head chainman, changes the rate of chaining to suit the weather, the health of the men, the degree of difficulty of the walking, the amount of chopping and the roughness of the country. To so set the pace as to get out of the party the maximum progress without breaking down the men is the problem. Of the weather, of the general health of the party for the day, and of the obstacles to speed from hour to hour, the head chainman must judge and act accordingly. Of the general conditions, roughness of country, and

[1]The "right of way" is the strip of land eventually to be owned by the railway company and to be occupied by its tracks, etc.

whether the party's strength must be saved for severer work or exposure later on, the chief of party can judge best. The greatest economy is attained when the chief of party instructs the head chainman on the general conditions, leaving the head chainman to use his judgment from day to day and from hour to hour. Obviously the man who sets the pace for chainmen and axmen should be one of their own number and not a topographer or instrumentman. There are head chainmen who, by their ability in setting the pace, will add fifteen miles per month to the distance run by the party and tire the party no more in doing so. If the chief of party makes no blunder which necessitates his throwing away surveyed line, and the assistant makes no local error requiring the chainmen to pull back, then the progress of the party, month by month, measures the efficiency of the head chainman in setting the pace under the existing conditions. When there is a responsible pacemaker the assistant does not need to urge on any of the men. It is their duty to keep up with their work and keep no other man waiting. If any man tires out, the chief of party has assigned his duties unwisely or the head chainman is exceeding the safe working speed. All men have their "off days," when they may fail before night. In such cases the assistant changes the work of that man, or sends him to drive the line-wagon, and uses the teamster in his stead until night. There is no chance for racing in a party so organized, and racing always means a poorer quality of work. Of course, a head chainman who does not take into account the level party in setting the pace is unfit for pacemaker. There are many times when a levelman cannot keep up with the transit. There is much poor instrument work due to racing between the transitman and the levelman. After many attempts to stop it on his own parties, the writer adopted this plan of making the head chainman the pacemaker and the result has been fewer instrumental errors, fewer sick men and less cost per mile of survey.

One requisite of an experienced head chainman for a locating party is cool judgment. The next quality is greater strength than any other man in the entire party. The last requisite is that he must be well disciplined in the sense in which we apply the term to a veteran soldier. If he possess these three traits he is quite invaluable. Time is often lost if the transit point be not well chosen by the head chainman. As the head chainman ranks next to the men doing an engineer's work of some form on the party, the rank and file of the party and especially the younger men and the recruits will take their "cue" from the head chainman. With the proper men for chief of party, assistant and head chainman, the *esprit de corps* of a party can be relied upon to be always of the best.

If the head chainman uses a link chain he must test it by a steel tape as often as once each week and keep its total length correct. His transit rod must be kept bright in its colors by painting or fresh wrapping with cloth. He must chain correctly, using good judgment as to the tension on his chain, and hold the same

relation to good transit work that the rodman does to good level work. He must see that the line is cleared properly. He must be a first-class axman and should have been a front axman, and "keep in line" like one. He is foreman over chaining and clearing the line and the work of axmen and stakeman. He is responsible in camp for the order, safety and condition of the men's sleeping tent.

THE RODMAN.

The Rodman reads and records the rod readings on all turning points, keeping a rod-book in which he keeps each height of instrument and elevation of turning points. He must call out these heights as well as these rod readings to the levelman, so that a constant check of the computations can thus be kept. With a self-reading rod he need not read the rod at stations except when told to do so by the levelman. He paces all "plusses"[1] and it is his duty to know where a "plus" is necessary. He carries a hand ax and peg-bag and drives "hubs" and reference-stakes which have been left by the chain party for use as bench marks, or he makes a bench mark on a tree in the usual careful manner.[2] During the day he obeys the order of the levelman entirely. At night he calls off the level notes for the levelman to plat the profile. He must be a careful, attentive and strictly honest man in all his work. He must be very active and hardy or the speed of the leveling will be expensively slow, by limiting the speed of the entire party. A good rodman should be able to run at a smart pace all day at his work. This running should not exhaust him at all. It is very important that he be able to judge heights of ground or he will waste time in choosing turning points. He needs this quality of selecting points for the level in greater degree than the head chainman needs it for the transit. An experienced rodman is indispensable when a student is the levelman on an old party. An old and first-class rodman strengthens a party. He can take the place of the levelman temporarily. He can take the place of the head chainman, if the rear chainman is unfit. It is poor economy to hire boys for rodmen. The levels are never so reliable, the levelman is always tending to fall behind and the boy cannot stand the work on the days when the country is such that the leveling is inclined to limit the speed of the party. If a young man wishes to begin work on an engineering party he either has sufficient education to make it worth while for a railroad company to make an engineer of him or he has not. If he has that education give him a level on a preliminary survey, and furnish him the very best old rodman on the road. If the young man has not the education indicated, give him the back flag and promote him to axman and beyond as he deserves. Between level-

[1] A "plus" is the distance beyond the stake to any point or object we wish to locate—as sta. 925 + 27. The plus is 27 feet from that point.

[2] A bench mark is described in Chapter iv.

man and rear flagman there is no middle ground for the boy or young man on this work.

THE COOK.

It is the verdict of most old chiefs of party that the Cook has given them more trouble than all the other members of the party. No cook is needed unless the party lives in camp, and it is probable that more parties would live in tents were it not for being troubled with a cook. This wide spread condemnation of this member of a party is unjust. If more chiefs of party understood the subsistence and care of men in camp there would be fewer poor cooks. The chief of party must see that food is seasoned and cooked in a uniform manner. The cook and chief of party must constantly watch and when the men cease eating one kind of food at once change to something else. Later change back. Comments on food during meals are never to be permitted. The men can complain to the chief of party, and he only makes criticisms or suggestions to the cook. A chief of party should keep away from the cook tent, save when he makes the round of the tents to see that all is in order. There is but one way to decide what to cook, whether to cook it much or little, and how to season it. Take a vote of the party and let the majority decide. Your cook will never demur to that decision. As for the rest, require the cook to keep his implements in order, the men in good health, and show him month by month what the subsistence is costing per man per day and per mile of line located. When you have a good cook such treatment will always keep him. It is not difficult to get a competent cook. It is quite difficult to get such a one who is manly and reliable. The greatest difficulty is in keeping him, and that is primarily the fault of a self-indulgent, incapable chief of party. The cook must know his business and a hotel or restaurant cook is better for the work than one of the "deep grease" cooks of the lumber or grading camps. He should be selected from the same general class of men as the rank and file of the party, namely, ex-soldiers, plainsmen, cowboys, etc. He must be used to the life and to the kind of men who make up the party. It is best to let him buy such food supplies as the people living in the country have to offer for sale. Some money should be supplied him for that purpose by the chief of party who keeps an open account with the cook. Receipts must be taken by the cook and turned in once a week to the chief of party who gives credit for them. A cook must be trustworthy or be made so by being trusted. Men can grow to be honest as men can grow to be dishonest. A chief of party and a boss teamster can attend to supplies better and cheaper and are safer than any clerk. A locating party needs no waiter, and the men in it had better wait upon themselves. A manly cook prefers to be better paid and have no waiter. Clerks and waiters are foreign to the spirit of a locating party.

We usually overpay cooks. It is a confession of weakness. A

cook should get about the same pay as a rodman. He should be of the same grade of man as the head chainman, rodman and boss teamster, and with about their average pay. His hours are very long and on camp moving days he works very hard. For this reason he needs to be hardy and not under size. Moving camp in the snow is severe work on cooks. No one need be told that good temper is priceless in cooks.

The main cause of trouble with cooks is that every fool in camp feels competent to boss the cook. If the cook is the man he ought to be he quits. If he is no man at all, he stays. This is why so many parties have unsatisfactory cooks. The fault lies in human nature, and the remedy is in the hands of the chief of party. It is no more difficult to have a good camp cook than to have a good boss teamster. It is easier to fill the place of cook than that of rodman or head chainman.

THE BOSS TEAMSTER.

The Boss Teamster is a man not needed when the party is quartered in farm houses or villages. He has general charge of the teams and teamsters, buys most of the supplies and attends to moving camp. He is sometimes called the camp boss. In a new and wild country where an experienced guide is required this guide has charge of stock and teamsters. This position is of greater or less importance according to the remoteness of the region surveyed and the dangers from Indians and scarcity of water. The boss teamster must be a first-class driver on all roads. He must be something of a doctor of animals. He should have many of the instincts of a guide or he will continually lose himself. Men from the old countries are wretched plainsmen or woodsmen, nor will they place confidence in the magnetic needle. As this teamster is the steward, he must be trustworthy and judicious in purchases. As his work is intermittent and his hours of work long he must be good tempered.

The cook and the boss teamster must get up in the morning at the same time and are relied upon to wake in time. After feeding the stock the boss teamster calls the other teamsters. The cook calls the men to breakfast at a fixed hour. Since the cook and boss teamster must get up first they need to go to bed first. This is a plain reason why they must sleep together.

THE REAR CHAINMAN.

The Rear Chainman comes next in order of importance, and his duty is already implied. He is responsible for correct "plusses" in chaining and for the correct numbering of the stakes, checking the stakeman's marking. It requires a man of considerable strength to hold steadily the back end of a chain on a station when the head chainman stretches it properly. He must be a careful man. He should be a good axman. All men on a locating party should

be capable of using either an instrument or an ax. In timbered country it is the strength of the party as axmen that controls the pace of the party. In prairie country the axmen are few in number, and when you reach a river or creek, a skirt of timber, brush and briars may retard the party because the axmen, while excellent, are too few. Chainmen, rodmen, and teamsters must then take their turn with axes, or use spare ones carried in the line wagon. The rear chainman should have been an experienced axman on line work, promoted for his carefulness and promise. In case of temporary illness of the rodman, the rear chainman should be given a trial as rodman.

THE FRONT AXMAN.

The first duty of the Front Axman is to keep himself on line. Not all men can do so. The writer is frank to confess that after long effort he has never been able to do this. By keeping the transit line accurately a good front axman reduces the chopping of timber or destruction of growing crops about 50%. Of course he reduces the labor of cutting out the line by the same per cent. He should be an exceptionally good axman, but the ability to keep a line is of more importance. No man is a first-class axman for work of a party unless he can chop either handed.

THE STAKEMAN.

The Stakeman marks the stakes and, in timber country, drives them. Stakes must be of good size, marked with plenty of chalk with figures looking as if made with a stencil plate. An axman who has artistic tendencies is best for this work. A head chainman or rodman can give him copies to follow. A figure must be gone over several times with the chalk to last well. The writer has seen stakes with the numbers still legible after eighteen years.

THE AXMEN.

One Axman beside the front axman is needed in prairie running. He drives the stakes, punching a hole for them in winter in northern latitudes with a wedge of forged steel shaped like a stake, driven by a sledge. For prairie work, whether in winter or crossing creeks with timber skirting them, a front axman, a stakeman and one other axman are all that are needed. In brush or timber one more axman at least, is required. Still another may be needed where large trees abound or brush and briars are thick. This applies to ordinary country, of course. An axman must be native to a timbered country. Canada, Michigan and the mountains of Virginia, Kentucky and Tennessee furnish good axmen. Other districts will suggest themselves to all. It is idle to employ a man from a city or a prairie country for such work. Get the very best axmen you can, pay them what they earn and have as few of them as possible. A large number of axmen are simply in each other's way.

Quality not quantity is desired. The writer located a line in the Ozark Mountains in Missouri with three axmen to cut out the line and the transit was not held back at all by them. In heavy chopping and hot weather one of the two chainmen or the stakeman changed off with an axman for an hour occasionally. The chief of party who does not use good judgment in selecting axmen is not a man who will show a low cost per mile of survey.

THE TEAMSTERS.

Two teamsters beside the boss teamster are needed for a camping party. These men should be fit to do axmen's work as well as to be good drivers and stablemen. They thus serve for recruiting the field party. In camp one of these men attends to getting wood and water, makes stakes for the next day's work and keeps the camp equipment in order and repair. With his team he helps take the party out in the morning and brings it in at night.

Whether the party lives in camp or in quarters at different points along the line there should be a "line wagon" and a teamster to drive it. A double team and lumber wagon is all that is needed for the line wagon of a camping party, but for a quartered party, the wagon needs to be large enough to carry the line party with stakes, lunch and spare tools. Either a heavy span or four lighter animals then are used to haul the line wagon.

THE REAR FLAGMAN.

The Rear Flagman's duty is to hold a transit rod as a backsight for the transitman, who alone signals him what to do. A little instruction and practice are needed to enable him to hold the rod vertically. The rear flagman must exercise a good deal of patience to keep himself attentive in work neither interesting nor stimulating. If there be boy's work on the party it is in this position. It is better, however, for the boy to be at school or at home. It is best to have the least expert axman or teamster in this position at the start and use the position later for testing the faithfulness of recruits. This completes the list of men in an ordinary camping party for prairie or open country.

EXTRA MEN AND HORSES.

When away from settlements, at least one extra man must be with the party to replace sick or injured men. When towns are so infrequent that the boss teamster can not be spared with his team long enough to make a trip between the days of camp moving, then a supply wagon is needed. A driver, four mules and an extra heavy wagon in addition to the three usual teams can keep an ordinary party in supplies and haul from some distance. The extra man should accompany him on the trips. An extra saddle horse is needed under the above circumstances, partly in case of accident to the regular saddle horse of the chief of party, and partly in case a messenger is needed.

Finally, all location parties should be double, that is there should be at least two men who can fill any one position on the party fairly well. Of course, the engineers should always be able to do the work of any of the engineers below them in rank. The chainmen and rodman should be able to do the work of any lineman below them in rank. All men not engineers should be axmen and all regular axmen should be teamsters. It is imperative that all locating parties have a second cook regularly employed to occupy one of the positions enumerated. A *good* party *should* be double, a *bad* party *must* be double or the chief of party will not be master after it leaves country where men can be recruited. That no man is indispensable is a fact that any organization needs to recognize.

There are unusual conditions under which railroads are to be located. For such conditions it is not necessary to explain the organization. The above is a usual, not a universal party arrangement and will form a safe working basis, to which to add where difficulties increase and from which to deduct where obstacles are few.[1]

[1]The following rates of pay of locating parties per month, including subsistence, on four railroads in the Middle West are herewith given. The Mo. Pac. Ry. rates of pay are actual and from the writer's party. The rates of pay of the other companies are practically correct, no doubt, but were obtained at the time from men on those parties, and are not official.

	A., T. & S. F. Ry. Standard on Chicago extension.	K. C., Ft. S. & G. Ry in Kansas.	St. L. & S. F. Ry. in Kansas	Mo. Pac. Ry in Kansas and Missouri.*
Chief of Party	$150	$125 to $140	$125 to $150	$150 to $165
Assistant	85	90	90	90 to 110
Transitman	75	75	75	80 to 85
Levelman	80	75	75	65 to 75
Rodman	45	50	50	40 to 50
Head Chainman	40	40	45 to 50	50 to 60
Rear Chainman	35	30	35	35 to 40
Axman	30	30	30	25 to 35
do	30	30	30	25 to 35
do	30	30	30	22 to 30
Rear Flagman	30	30	30	20 to 28
Boss Teamster	30	30	30	35
Teamster	30	30	30	30
do	30	30	30	25
Cook	55	50	50	40 to 55

*This party never had an "iron clad" payroll. The men were hired at low rates and raised in pay as each man deserved.

EQUIPMENT.

The equipment is of two kinds, camp and field equipment with a small amount of supplies for drafting. Of the field equipment, the instruments will now be treated in detail, although some of the tools will be spoken of under the subject of preliminaries. Engineering instruments scarcely need to be designed for location work but not all types made are suitable, and some attachments are especially desirable.

Transit.

The transit should be of moderately high magnifying power, have clear glasses and erecting telescope with sharp definition. Object glasses and verniers should be shaded and the metallic surface be bronzed or covered with cloth or felt. Bright surfaces tire the eyes, and tired eyes cause wavy tangents. There should be stadia wires, a long bubble and a shifting head. It is preferable that the verniers be under the ends of the telescope and that tangent screws be single with a spring action. The limb should be so graduated as to give very plain markings and the verniers read to single minutes. With the proper transit, the transitman should need no vernier glass to read to minutes with certainty. When a beginner is running a transit he should not be allowed to have a vernier glass or an adjusting pin with him. The tripod needs to be of good length to allow spreading out in high winds and yet enable the transitman to stand nearly erect in sighting. A vertical circle or arc is needed. A gradienter is of doubtful use. With a transit rod marked in feet and a long bubble with its accompanying clamp screw on the telescope, the telescope can be readily pointed along any grade line by holding the transit rod at 100 ft. from the transit, leveling the telescope and sighting then to the point above or below the level point on the rod a distance equal to the gradient. The reconnaissance, however, and not the gradienter should tell whether a hill is too steep.

Level.

The level should have first-class glasses and a bubble that is not very sensitive. A bubble with a long radius is more accurate than needed, and by its use a levelman is handicapped in making the speed he should. Reading station heights to tenths and turning points to hundredths with a bench mark every twenty-five stations, are conditions which make sensitive bubbles needless. A 20-in. Wye Level of some heavy pattern is the best, ordinarily. Weight is needed as the winds jar a level more than a transit. Cross hairs should not be very fine. Leveling screws should be long and the threads rather coarse. The tripod legs need plenty of length for stability. There should be as little bright metal as possible.

Rods and Chains.

The level rod should be of the Philadelphia type and the figures marked in feet and tenths so the levelman can read it on stations.

The chain should be a heavy one, if a linked chain, and corrected for total length every week. The ordinary wear will shorten it a full link in four to six months. The writer has used a ribbon chain or "engineer's chain tape," marked in feet, with good results. Their first cost is less, they are more accurate, lighter to use and give less trouble in mud or timber than a linked chain. They will wear longer, and their length is not affected by wear. They will break unless chainmen are experienced and careful.

The transit rods should be of hexagonal cast steel, five-eighths of an inch in diameter and seven feet long. This diameter allows the middle third of the rod to be covered by the cross hair of the best transits at 1,200 ft., which is the economical length of transit sight. The rod can be bisected better under these conditions. The length specified will show a little of the rod above the head of the head chainman or back flagman, which aids in seeing and bisecting the rod. Longer rods are a temptation to do poor work by sighting to their tops in rough country, and delay the head chainman by being unwieldy in the woods. These rods are covered every few days with strips of new red cloth alternating with white cloth for each foot in length of the rod. Wrapping with cloth is better than painting, and ensures sharp coloring and close sighting. The rods are indestructible and are far less expensive in the end than wooden rods.

Sundries.

Each axman selects an ax for himself. Extra axes, brush hooks, corn knives, etc., should be always in the line wagon which follows the party with stakes, food, water and extra clothing.

An extra transit, level and rod are necessary in running long lines in new country, for use in case of accidents. The drafting instruments are an ordinary field or pocket set, consisting of large and small triangles, straight edge, pens, inks, etc. Manila drawing paper and tracing cloth are needed for the map. Profile paper should be 15 ft. to the inch vertically, for the record profile. This gives more room for notes and is now commonly used. Profile paper 25 ft. to the inch vertically, is more compact for preliminary profile, and therefore desirable for carrying in the pocket or on horseback. A liberal supply of note books and the usual stationery complete the things needed in the stationery chest. The chest has double lids, and when firmly supported at the proper height and its top lid opened and held horizontal by a bar driven into the ground, may form the drawing table. A drawing board on horses is better. This completes an ordinary field and office equipment.

Tents.

Should the party live in camp, the added equipment for the size of party mentioned may be as follows: Three teams with heavy wagons are needed to haul the camp outfit. Three 14 x 16 ft. tents with flies are needed for office, quarters and cook tents. If the climate be cold a tent 16 x 24 ft., with fly, is needed for the three teams and saddle horse. All tents should be made of 12 oz. duck. It is economy to keep the animals in condition and use them wherever possible to save the men's strength for line work.

Stoves.

A cook stove with its necessary utensils is always superior to an out-door fire for cooking the food. But a cast-iron stove or range is heavy and soon destroyed by jolting in moving. The middle course is to have a stove made of steel and sheet iron with cast iron firebox and grate, all united together. This is very light and practically indestructible in moving. A four-holed top is large enough. The top should be one-eighth inch thick. The stove should have no legs, but rest on a brick at each corner. The grate should be adapted to either wood or soft coal.

The only suitable heating stove for camp use in the office and quarters tents is the Sibley stove of the regular army, designed, we understand, by General Sibley for heating tents for soldiers' quarters. It is well known to western men and is essentially a cone or funnel of sheet iron, about three feet high. Its larger end, which is thirty inches in diameter, rests on the ground, while its narrow top fits into a five-inch stove pipe. A damper is needed in the pipe. A door is placed in the side. There is no bottom to the stove, and the wood fire is built on the ground inside the stove. For coal burning use the circular grate from an upright boiler, setting it up on brick to get a draft under the grate. Cut an opening at the bottom, on the back side of the stove, as the ashes must not accumulate and melt the grate. These stoves are economical and will keep men comfortable on the plains in weather 25° below zero. There is but one place for a stove pipe to pass through a tent without giving trouble in a wind storm, that is through the ridge pole. Cut one foot out of the ridge pole and bolt a heavy iron strap on each side, curving it out where the pole is cut away, so as to form a thimble for the pipe.

QUARTERS.

In the office tent are quartered the following men: chief of party, assistant, transitman, draftsman, levelman and rodman. The stationery chest, which may form the drafting table, belongs in the office tent. There should be a small box with medicines provided for the party, and kept in this tent. In the middle latitudes of the United States each man needs in winter one pair of blankets and two quilts. Two men usually sleep together.

There should be for each two men a piece of enameled cloth, such as used for carriage aprons. This is placed under the bedding to keep out the dampness rising from the ground and is also used to protect the bedding from storms when moving camp. Straw or hay placed about six inches deep on the ground forms the mattress on which to spread the bed. Overcoats make pillows. Under no circumstances should any man be given more or better bedding than another. In the sleeping or second tent are quartered eight men: head chainman, rear chainman, two axmen, stakeman, two teamsters and back flagman. This tent will hold more men comfortably,

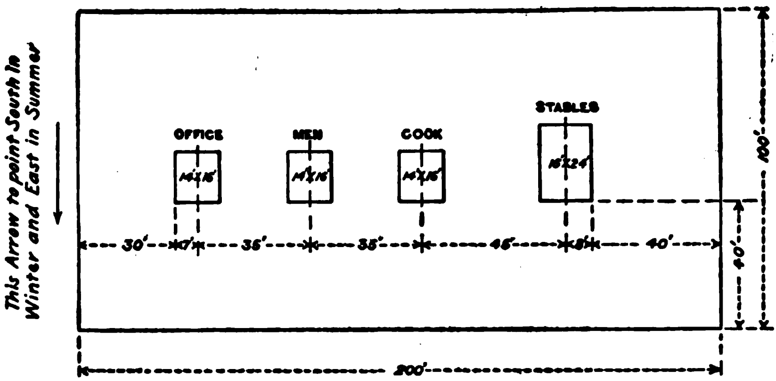

Fig. 11.

if necessary. Each man has the usual allowance of bedding and accommodations for sleeping. The head chainman has charge of this tent. He keeps it safe from fire or from storms, preserves order among the men in it, and is responsible to the chief of party for all that occurs in it. In the third or cook tent, the cook and boss teamster are quartered. Their bedding is similar to that of the others. In the Indian country of America or among other hostile natives no man should sleep alone in a tent. Moreover, men

exposed to the weather are liable to sudden illness at night; making it better to keep together.

In camp arrangements it is best to follow the practice of the regular army and put the fronts of the tents in line and so spaced as to allow only a passageway between. The ground plan with spacing is shown in Fig. 11 and the plan makes the camp offer the least surface exposed to the force of the wind. Only one tent can suffer much from side winds. A wind against the backs of the tents is little to be feared. This camp can least stand a wind that first strikes the stock tent, for this tent is highest. It is usually best to face the tents to the east in the summer and to the south in the winter. A camp near a creek, several feet above the stream and where the timber and nearby brush breaks all winds from the back

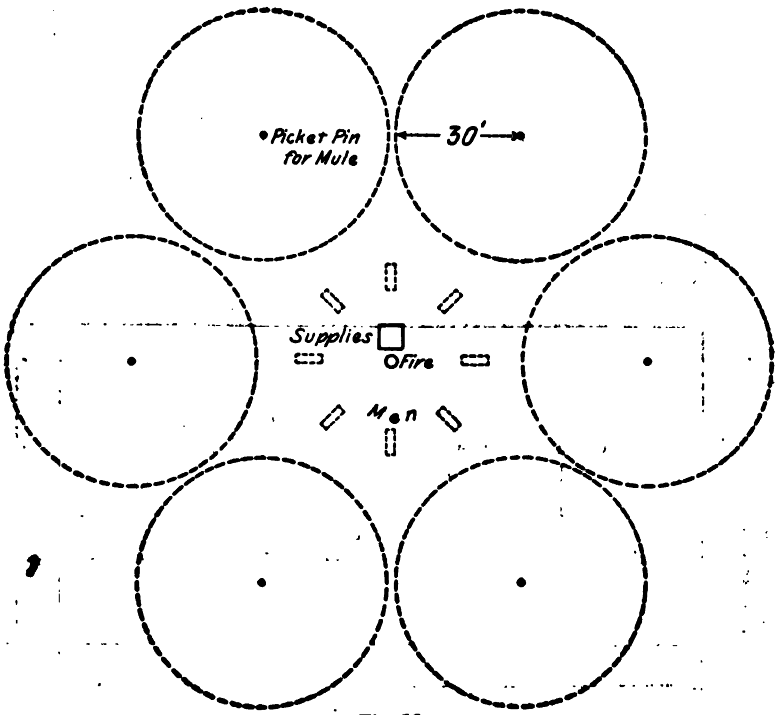

Fig. 12.

and sides of the tents, is the ideal camping site for winter. In summer a wind-break of timber at a little distance from camp is better. In winter the camp site should be as deep below the ground level of the country as possible and where wood and water are convenient. In summer the camp site must not be below the general level of the country, but be behind a rather distant wind protection. Water from a well is desirable in summer, but fuel is of small

necessity. Well selected camp sites are an aid to the work, provide an insurance against storms upon the company property, and have a great influence upon the health and contentment of the men.

A locating camp in the country of hostile Indians has to be modified to suit those conditions. The camp may be secreted or made less conspicuous. This plan is well adapted to small parties or in dry countries where it is difficult to find enough water for a large number of men or animals. The tents are not put up. They are too conspicuous, and when a light is inside a tent it can be seen for a surprising distance on a dark night. The sketch shown in Fig. 12 makes this camp arrangement clear. The mules or plains horses will smell an approaching Indian and come close to the man sleeping on that side of the camp. This man speaks to the next man on one side and quietly wakens him. This continues until the man on the other side of the man first awake has spoken to him. All the men are thus awakened. None rise up until more noise is heard or an Indian seen. The object is to guard against surprise, surely, and to avoid if possible having some men stand guard at night. This plan worked all right among the Apaches in Texas.

Fig. 18.

A more usual plan than the one just shown is by corraling the stock at night inside the parked wagons, and posting guards. A larger party, more transportation animals, and more water are required. The accompanying sketch, Fig. 13, is from the journal of a transitman on a locating party in Dakota in 1871, among the Sioux Indians. It is fairly typical for the conditions. Each of these last two sketches of camps has at least historic interest.

COOK'S OUTFIT.

The cook's equipment need not be fully stated here. Enough utensils of the plainest, most indestructible kind should be provided. Granite iron is especially suitable. No crockery or glass is allowable, and table dishes are of the cheapest. A capable cook knows what he needs. No other cook will answer. His mess chest, forming his kneading table and containing his flour, should be as

wide as will go in the wagon box, high enough to carry safely a case of canned goods below the top box, and so long that when packed full four stout men can just get it in the wagon. It will then hold all the cook's equipment and save losses. The secret of camping without losses of outfit is in having the equipment boxed in as few packages as possible. A dining table is needed. Men must all sit down comfortably at the same table in the cook tent to rest and eat. The more a man rests and eats at night the more help he can give to a chief of party in cutting down the cost of located line per mile. If the men are obliged to sit around in the weather with their plates on their knees and eat, or stand up to a table in a cold tent, the party cannot be expected to lower records. This dining table should be at least 3 ft. wide and 12 ft. long. When the legs and brace-rods are folded up under the table for moving it is 2 ins. thick. Four benches are required, 1 ft. wide, 6 ft. long, and when the legs are folded under for moving, the benches are 5 ins. thick. A half dozen camp stools complete the seating accommodation for the entire camp.

THE STOCK TENT.

In the fourth or stock tent three teams and a saddle horse are quartered. This tent can be opened at each end. The great difficulty is in making a manger to which to tie three teams and a horse, and in having it secure and of little weight or bulk. Drive eight rods in the ground, in line across the middle of the tent, leaving their looped tops at the right height for the feedbox. From each side run a rod through these loops bolting the two rods together in the center. Fasten two ropes in the loops at each outer end of these horizontal rods. Run these ropes through a large eyelet made in the tent and reinforced with leather. Fasten each of these ropes to iron pins driven in the ground some distance from the tent, these four pins being so set as to guy the horizontal rod, on which the feed boxes are hung, resting against one of the vertical rods. Tie the animals to the rods at the top of the manger and feed hay on the ground. The stock tent is in charge of the boss teamster, who is responsible for it and all transportation matters.

FOOD SUPPLIES.

Supplies are the bane of locating engineers at the beginning of camp life. No two camp men have the same views on the question. The proper way is so to feed men that you will in the end get the most good work out of them for each dollar they cost the company. As their salaries cost on an average from three to four times the cost of feeding them, their subsistence cannot economically be below what is needed to keep the men always in good health, flesh and spirits. It follows that whatever a doctor would consider an advantage in diet for the men is economy for the company. Men living in tents and working regularly in the open air need nothing to tempt their appetites. If the bill of fare and quan-

tity provided per man per day be based on the army ration we shall get the best economic subsistence. (For Subsistence List see close of chapter.) The army ration weighs about 2.5 lbs. For 16 men, 20 days' supplies would weigh 1,800 lbs. To this must be added at least 200 lbs. of extra flour and meat as reserve supplies, or 2,000 lbs. total for 20 days' supplies for minimum party in unsettled country. Six mules and one saddle horse are the least number of animals to be taken, and 7 lbs. of grain each per day is about the least allowance for forage, even with good grazing. The forage adds another 1,000 lbs. to the weight of supplies. One ton and a half of supplies, therefore, is a minimum allowance for a minimum party for regular work. Usual equipment can be hauled with these supplies by three good ordinary teams over any reasonable country.

It is wise to supplement this ration in the interests of economy. As much of the food added to the bill of fare is canned vegetables and fruit which contains much liquid, the weight of the supplies tends to exceed the weights given. Dried vegetables and fruits are more economical in weight, but not otherwise. The liquid of the canned tomatoes taken once during the day will enable a man to run an instrument ten hours under a hot sun without other liquid. Tomatoes are the best camp vegetable for hot weather. In warm weather and low elevation use the vegetables and tart fruits and coffee, while in cold climates and higher elevations use meats, fruits with heavy syrups and tea. Purchase enough of these supplies for the party for a fortnight, as you have accommodation for that amount in your three wagons. Of cook's seasonings, pepper, coffee and spices, take a double portion, as the bulk is small. The writer once sadly lessened the efficiency of a veteran party by bringing it down half way to sea level and into a temperature 40° higher *without reducing the quantity of heavy food and giving vegetables and lighter diet instead.*

Remember that what you can use of the products of the country where you are camped is usually the cheapest food. Use fresh milk and eggs liberally where you can get them. Use fresh meats and vegetables, keeping the cook informed as to the prices of prepared supplies so that he can buy intelligently. Show your cook each month what the subsistence has cost per day per man, and how many day's work the men of the party have lost through illness. Sickness and rate of board per day are his barometers. At once it will be evident that any outlay for food that is necessary to avoid illness is economy. Drivers, teams and wagons for hauling supplies when needed should be a part of the field party. The chief of party then relies on his own organization and can be held answerable for results.

Were food supplies the only kind that must be hauled, the problem would always be simple. Water is more necessary and cannot be so readily transported. Dry camps are the bane of railroad location. A succession of them soon makes locating work most difficult. One dry camp between those where water is found necessi-

tates a few water barrels added to the ordinary equipment. Take a little water along as you move away from the previous camp, put the animals on short allowance of water and drive them back once a day to the former camp. This is usually all that is required. In extreme cases a water tank-wagon and four mules must be added to the field party to haul the water. A chief of party under such conditions needs a reliable guide, well acquainted with the water holes of the region. The guide acts then as boss teamster. The discipline of a party in a dry country needs to be excellent, or the party will finally come to grief. A field party "stampeded" for water is a sad sight. Unselfishness is the first requisite for a man on parties in such countries.[1] On the plains all men are equal, and in all deprivation pure democracy must be the rule. The engineer who is not willing to thirst and hunger and freeze *more* than any axman or teamster is not fit to be a member of such a field party.

FUEL.

Fuel is a form of supplies that gives trouble only on our northern plains in winter. It is only less troublesome than water supply. Living in tents in a timberless region and moving camp frequently, where cold is constant and blizzards liable to occur at any hour, make it necessary to provide coal in advance. This supply cannot be small, for it must last through one of these storms. Soft coal is needed, with a little engine wood for kindling. The fuel must be kept in carload lots at the nearest railroad stations, and taken along in considerable quantity with added teams as the party starts. It must be hauled some ten miles ahead and stored or "cached." The fuel must be kept in sufficient quantities within easy reach, and the boss teamster can then keep the camp well supplied. The blizzards are dangerous, and vigilance only can save accident from this cause. Of course, the cook stove must be arranged to burn any wood or soft coal. The Sibley stoves, as already explained, are readily converted from wood burners to soft coal burners.

RECAPITULATION.

In recapitulation of the subject of organization, equipment and subsistence of a party it may be said that much can be done to make a party comfortable and to keep it in good condition at all times by experienced camp management. Camp fare should be such that men prefer it to the best hotels that exist where new railroads are usually built. But in exposed regions no camp management

[1] The old guide of the Texas & Pacific Ry., Patrick Dooling, sent out to "take care of" the first party of which the writer had charge, laid down at the outset of that trip this law: "Pass around the canteen with only a pint of water in it, when men have had no water for twenty-four hours. The *men* will wet their lips and take one swallow to hold in their mouths; the *things* will drink like mules." There are many excellent engineers who might not stand that crucial test. They should not join field parties in dry countries.

can keep a party of green men in condition. Organization should not be made to fit the men—the men should fit the organization. Equipment should not be made to fit the men. The men must fit the ordinary equipment. If an engineer shows no disposition to lead the life of a railroad location party, he must do other work than field location. The men who are not engineers must be hired from the classes of men used to exposure, to severe work, to dangers, and to discipline. Men who have served in an army are excellent. Old scouts, plainsmen, some cowboys and generally that class of men who learned to use tools and teams as boys and have gone to new countries to better their condition, are the best material. Equipment can be made sufficient to keep them comfortable and happy. Equipment for a party in a hot desert or in a treeless region, with a blizzard raging, cannot be economically made sufficient for any other kind of men. We must not attempt too much in the way of equipment or camp management. Then life and health can be maintained under almost any condition ever encountered in the work of railroad location.

ARMY RATIONS.

According to the United States army regulations "a ration is the established daily allowance of food for one person." A ration is as follows:

12 oz. of pork or bacon or canned beef (fresh or corned),
 or 20 oz. fresh beef,
 or 22 oz. salt beef.
18 oz. soft bread or flour,
 or 16 oz. hard bread,
 or 20 oz. corn meal.

And to every 100 rations add:

15 lbs. beans or peas,
 or 10 lbs. rice or hominy.
10 lbs. green coffee,
 or 8 lbs. roasted coffee (or roasted and ground),
 or 2 lbs. tea.
15 lbs. sugar,
4 quarts vinegar,
4 lbs. soap,
4 lbs. salt,
4 oz. pepper,
1 lb. 8 oz. Adamantine or Star Candles,
4 lbs. yeast powder (to troops in the field).

On reconnaissance with pack trains the emergency ration adopted by the United States army, June 30, 1896, forms the best basis for supplies. It is as follows:

16 oz. hard bread, 10 oz. bacon, 4 oz. pea meal, 2 oz. coffee (roasted and ground, with 4 grains saccharine), or one-half oz. tea (with 4 grains saccharine), 0.64 oz. salt, 0.04 oz. pepper, 0.50 oz. tobacco.

A fodder ration for a horse is 14 lbs. hay and 12 lbs. oats, corn or barley.

An emergency ration is not intended for use over ten consecutive days. An engineer would need to liberalize it somewhat.

PACK TRAIN.

The following is a complete equipment and subsistence list for a pack train for use on reconnaissance. The party consists of the engineer, guide, cook and packer—four men. The supplies are for 30 days. The stock must live by grazing. The pack mules start with 300 lbs.

4 saddle horses, equipped.
4 pack mules, equipped.
1 A-tent with hinged ridge pole and end poles with a socket joint in each.
8 prs. double blankets.
8 canvas covers for blankets.
1 Dutch oven.
1 coffee pot (1 gal.)
1 frying pan.
1 bread pan.
6 knives and forks.
6 spoons.
1 butcher knife
6 plates (granite iron).
6 cups (granite iron)
120 lbs. bacon.
150 " flour.
15 " beans.
10 " green coffee.
15 " sugar.
2 quarts vinegar.
1 lb. candles.
2 lbs. soap.
4 lbs. salt.
2 oz. pepper.
3 lbs. yeast powder.

(This equipment was used by Patrick Dooling, of Quanah, Texas, the guide of the Texas and Pacific Railway, to whom the writer is indebted for his first lessons in camp management.)

SUBSISTENCE LISTS.

The following are subsistence lists for the kinds and quantities of food necessary for a party of 16 men for a period of 30 days. Fuel and water are supposed to be obtainable in the country. These lists represent a wide range in climate and many different authorities. Any of these lists is safe and practicable. The articles are placed in alphabetical order for convenience.[1]

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[1]The list of the Mississippi River Commission was furnished by Mr. J. A. Ockerson, a member of that Commission. That men are properly fed on such work the writer can testify from experience. In the language of an executive officer of the Commission, the list "draws the line between necessities and luxuries." It gives variety of food. The list of the Forth Worth and Denver City Railway fairly represents the subsistence of Mr. Gould's parties in Texas in 1882. It was used by the writer, and was revised by the late W. J. McNulty, the Assistant of the party in Texas. The list of the Union Pacific Railway Company is the one used by Mr. Van Auken's party in 1889, as furnished the writer by a member of the party. The list of the Southern Pacific Railway Company was used by Mr. C. E. Moore's party in California in 1895, and is furnished through his courtesy. The list for the Great Northern Railway was furnished by Mr. J. D. Mason, Principal Assistant-Engineer of that line, assistant on the writer's party, to whom the writer is indebted for many suggestions. The list of the Missouri Pacific Railway shows the subsistence of parties in about the latitude of Kansas, therefore neither north or south. It is the list for the writer's party from fairly corrected notes from year to year. Later this list has been corrected by Mr. Walter Davis, Head Chainman on those parties for 1,300 miles of line, whose observation and judgment in camp matters is very reliable. The list is liberal, but economical. There is nothing to be wasted and the party can be kept in good health.

SUBSISTENCE LIST FOR 16 MEN, 30 DAYS.

	Miss. River Com'n.	Gould Line in Texas.	U. P. Ry. Rocky M'tns.	So. Pac. Ry. California.	Gt. Nor. Railway.	Mo. Pac. Railway.
Allspice.............Lbs.	0.2	....	1	....	0.5	1
Apples, evap........ "	10	60	30	....	50	10
Apricots, canned..... "	....	24	....	....	....	20
Bacon.............. "	30	50	48	....	100	40
Baking Powder...... "	3	18	16	12	10	12
Beans, navy......... "	35	48	48	100	50	75
Beef, fresh.......... "	575	Occasional	400	300	As practicable	480
Beef, corned......... "	100	24	....	....	48	16
Beef, canned........ "	4	50	....	96	....	48
Beef, dried.......... "	6	5	....	....	25	12
Blackberries, canned. "	15	32	25	....	....	24
Butter.............. "	40	....	64	60	60	60
Candles............ "	15	15	54	80	50	....
Catsup, bottles......	3	6	....	12	6	12
Cheese..............Lbs.	8	8	....	10	25	12
Cherries, canned..... "	....	48	....	....	48	48
Coffee, roasted....... "	45	50	48	40	50	40
Corn, canned........ "	15	48	32	....	48	48
Corn Meal.......... "	196	100	32	....	30	50
Corn Starch......... "	0.5	6	8	....	10	6
Crackers............ "	10	20	....	....	20	20
Currants, Eng....... "	2.5	5	....	10	10	10
Eggs............... "	....	....	....	....	....	As practicable
Flour, wheat......... "	490	560	480	250	400	480
Flour, graham...... "	5	25	....	50	....	25
Fish, mackerel...... "	12	24	....	48	....	24
Grapes, dried........ "	....	....	....	20	....	....
Ham .... "	40	260	160	160	100	200
Honey..............Gals	....	....	....	5	....	....
Hominy ....Lbs.	15	24	....	....	....	....
Kerosene ....Gals	....	....	....	....	....	5
Lard ....Lbs.	25	75	48	40	40	40
Lemon extract....... "	0.3	0.5	1	....	1	1
Nutmeg.............Ozs.	1	1	....	....	1	1
Matches, small boxes.	1 doz	2 doz	3 doz	2 doz	1 doz	4 doz
Milk, fresh..........	....	....	....	....	All required	All practicable
Milk, condensed......Lbs.	40	48	48	48	48	12
Mustard .... "	0.5	1	1.5	....	2	2
Oats, rolled......... "	10	25	54	50	40	30
Onions............. "	85	85	112	85	20	50
Peaches, canned..... "	15	24	....	....	48	48
Peaches, evap........ "	8	10	30	25	50	20
Peas, canned........ "	15	....	32	....	48	....
Pepper, black........ "	1	2	2	....	1	2
Pie fruit, assorted.... "	....	....	....	....	....	24
Pickles, ...Gals	2	5	8	5	5	5
Potatoes, Irish.......Lbs.	900	200	560	500	400	500
Plums, canned....... "	....	48	....	....	....	48
Prunes, evap........ "	5	25	25	50	....	....
Pork, salt........... "	....	....	....	....	....	12
Raisins............. "	0.5	5	....	7	10	10
Rice......... ..... "	25	90	32	60	25	60

Subsistence List for 16 Men, 30 Days.—Continued.

	Miss. River Com'n.	Gould Line in Texas	U. P. Ry. Rocky M'tns.	So. Pac. Ry. California.	Gt. Nor. Railway.	Mo. Pac. Railway.
Salt .... Lbs.	2	32	40	20	20	20
Salmon, canned ...... "	8	12	....	....	....	6
Sauce, pepper ...... Bot.	....	....	....	12	....	3
" Worcestershire "	1	6	....	6	....	3
Soap, laundry ...... Lbs.	25	18	48	50	50	50
Sugar, A ...... "	100	100	144	100	150	100
Syrup, N.O. ...... Gal.	3	10	16	....	5	5
Tapioca ...... Lbs.	....	....	....	....	10	5
Tomatoes, canned ...... "	96	72	64	72	96	72
Turnips ...... "	50	....	....	50	....	25
Tea ...... "	2	2	8	10	10	10
Vanilla, ext. ...... Oz.	....	4	4	....	1	2
Vinegar ...... Gals	3	5	6	5	1	5
Wheat, cracked ...... Lbs.	1	10	....	....	....	10
Yeast, cake ...... "	....	2	1	....	2	1

NOTE.—There will be used about 5 lbs. of smoking tobacco and 10 lbs. of chewing tobacco.

The wide range in quantities used by different companies is noticeable in some articles. This is partly due to climate and partly to customs where men are employed. In the smaller articles it is likely that some of the lists are not complete as given to the writer. Any one of these lists would serve the purpose. A casual comparison of the tabulated lists will enable one to avoid any error or omission that would be felt later.

FORAGE.

A locating party in camp ordinarily uses three teams and a saddle horse—a total of seven animals. The forage required for these animals in 30 days is about as follows:

Oats	1,000	Lbs.
Corn, shelled	3,000	"
Hay	4,000	"
Straw	1,000	"

This is used where there is no grazing. The straw is for bedding the animals and the men at each camp. Hay is used for bedding where straw is not conveniently procured.

EQUIPMENT LIST FOR LOCATING PARTY.

Required for Line Work and Office Work Only.

1 Transit-Vernier reading to single minutes without use of magnifying or reading glass, erecting telescope, level on telescope, vertical arc, stadia.

1 Level, 20-in. Y, not too sensitive bubble.

1 Level rod, Philadelphia, painted feet and tenth figures, reading vernier to 0.01 ft.

2 100-ft. chain tapes (ribbon chains).
2 50-ft. metallic tapes.
2 Transit rods, ⅝-in. octagonal cast steel, 7 ft. long (each). wrapped with alternate strips of red and white cloth.
10 Yards red calico.
10 Yards white muslin.
1 Plumb bob string 25 ft. long, for intersections.
2 Hand axes, sharpened and headed like broad axes.
3 Axes, Poll, 4¼ lbs., with leather scabbards for same.
2 Small plumb bobs for chainmen.
1 Bush hook.
1 Mattock.
2 Corn knives.
2 Lbs. forester's crayon chalk, red (a little blue, black and yellow chalk).
5 Lbs. tacks, white metal flat tops, indented heads, best.
3 Stake straps or sacks.
1 Water keg, 10 gals.
2 Small canteens.
1 Lunch basket.
1 Coffee pot, 2 gals.
12 Transit books.
12 Level books.
1 Roll thin profile paper, Plate A.
30 Yds. drawing paper, sheets.
30 Yds. tracing cloth.
6 Drawing pencils, 2 H. 4 H and 6 H.
12 Pencils, Nos. 4 & 5 Faber.
6 Rubber erasers.
1 Set drawing instruments, small.
2 Large and small celluloid triangles, 30°, 60° and 45°.
1 Straight edge.
1 Spool black silk thread.
1 Pyramid pins.
6 Bottles drawing ink, red, blue, black and chrome yellow.
1 Bottle mucilage.
1 Pint combined and copying ink.
12 Scratch blocks.
3 Red and blue pencils.
1 Dozen blotters.
1 Box rubber bands.
6 Packages envelopes, small.
1 " " large.
6 Pen holders.
1 Box falcon pens.
1 Dozen pens, No. 303.
1 Dozen pens, No. 404.
1 Ink stand.
6 Pads letter paper.
6 Erasers.
3 Qrs. foolscap paper.
2 Balls hemp twine.

Other stationery of company in office forms, pay rolls, reports, etc.
1 Copy Butt's Field Book.
Stationery chest, with inner and outer lids.

Additional for a Camping Party.

In addition to the above list of equipment there will be needed for a party camping out under ordinary conditions the following camp equipment and transportation for 16 men and 7 animals:

Stable Tent.

1 Stock tent, 12 oz. duck, 16 x 24 ft., 5-ft. walls, with fly, open both ends.
3 Teams with harness and full equipment.
3 Wagons, one 3½ ins., two 3¼ ins., double boxes, brakes, feed boxes.
4 Spring seats.
1 Saddle horse, well bred, good size, to suit chief of party.
1 Grind-stone.
10 Pointed iron pins with eyes, and two rods each 8 ft. long.
7 Steel picket pins.
150 Ft. of 1-in. guy rope.
10 Steel guy pins for same.
3 Tubular lanterns.
1 Shovel.
2 Stable forks.
3 Curry combs and brushes.

Cook Tent.

1 Cook tent, 12 oz., 14 x 16 ft., 4-ft. walls, open one end, with fly and extra center pole.

120 Ft. of 1-in. guy rope.

4 iron guy pins for same, each 1 in. diam., 18 ins. long, sharpened eyes at top.

1 Mess chest, wide as will go in wagon, 2 ins. lower than upper box and 6 ft. long, partitioned, mixing board over one-half as large as inside lid.

3 Doz. granite iron plates.
3 Doz. " " cups.
3 Doz. iron knives and forks.
3 Doz. spoons, small.
1 Doz. spoons, table
3 Spoons, iron, large.
2 Butcher knives, large and small.
1 Carving knife and fork, with steel.
2 Can openers, large and small.
2 Pepper boxes.
3 Granite iron vegetable dishes.
18 " " soup dishes.
2 " " milk pitchers.
3 " " butter dishes.
1 " " coffee pot, 2 gal.
1 " " teapot, 2 gal.
2 " " pudding dishes.
3 " " frying pans, large.
2 Small frying pans.
1 Tea kettle.
2 Stew pans.
3 Granite iron pots with covers.
2 Bread pans.
1 Cake mold.
1 Coffee mill.
1 Flour sieve.
1 Rolling pin.
1 Griddle.
1 Large dish pan.
1 Bread pan, 15 gal.
2 Dippers, small.
4 Dippers, large.
2 Salt cellars.
1 Potato masher.
1 Egg beater.
1 Dinner box.
1 Water barrel.
6 Water buckets.
1 Water keg, 5 gals., for line use.
1 Milk can, 3 gals.
2 Granite meat platters.
3 Granite iron fruit dishes.

1 Meat saw.
2 Washtubs, large and small.
1 Wash board.
1 R. R. pick.
1 Dining table, folding legs, seating 16 men.
4 Benches, folding legs.
1 Wash basin.
2 Camp stools.
1 Hatchet.
1 Lantern.
2 Lamps.
1 Axe.
1 Shovel.
1 Cook stove, cast-iron grate for wood or coal, steel body riveted.
6 Joints pipes, no elbows. Pipe through ridge.
2 Pairs blankets.
4 Quilts.

Sleeping Tent.

1 Sleeping tent, 12 oz., 14x16 ft., 4-ft. walls, open one end with fly.
120 Ft. of 1-in. guy rope.
4 Iron guy pins, extra center pole.
1 Sibley heating stove, conical, 30 ins. diam., 36 ins. high,
6 Lengths 5-in. pipe.
4 Camp stools.
1 Lantern.
1 Lamp.
1 Axe.
2 Water buckets.
3 Wash basins.
1 Spade.
1 Large oil can.
8 Pairs blankets.
16 Quilts.

Office Tent.

1 Office tent, 12 oz., 14x16 ft., 4-ft. walls, open one end, with fly and extra center pole.
120 Ft. of 1-in. guy rope.
4 Iron guy pins.
1 Sibley stove, conical, 30 ins. diam., 36 ins. high
6 Length 5-in. pipe.
4 Camp stools.
1 Lantern.

1 Lamp, large burner, for drafting.
1 Axe.
2 Water buckets.
2 Wash basins.
1 Shovel.
1 Stationery chest, outer and inner lids to form drawing table.
6 Pairs blankets.
12 Quilts.
1 Extra set of poles for 14x16 ft. tent.
1 Sounding rod, 1-in. gas pipe, 5 sections each 6 ft. long, pointed and capped.

In case the party works in winter in a middle latitude there will be needed 16 pairs of blankets additional. These are kept in stock in the office tent, except when in use. A forged steel wedge is needed to punch holes in frozen ground for stakes, and an 8-lb. striking hammer is needed to drive it.

Unless the party be in civilization a box of tools for maintenance of equipment is needed as follows:

Tool Box.

1 Carpenter hammer.
1 Horse-shoeing hammer.
1 8-Lb. striking hammer, sounding, etc.
1 Monkey wrench.
1 Brace, 8 bits, assorted sizes.
1 Hand saw, cross-cut.
1 Hand saw, rip.
1 Handle, of awls.
2 Cold chisels, large and small.
1 Draw knife.
2 Screw drivers, large and small.
1 Rasp, blacksmith.
1 Rasp, wood.
2 Files, flat.
1 Punch.
1 Hammer punch.
1 Box rivets, assorted sizes.
1 Pair pincers (small).
1 Pair pincers (large), horseshoeing.
1 Pliers.
3 Whetstones.
1 Gimlet.
2 Doz. 2-in. rings, for tents.
2 Sheets tin, roof guards.
1 Piece leather, wall guard for stock tent.
1 Saw clamp, ½ doz. three-cornered 6-in. files.
1 Saw set.
1 Rivet set.

If the party be away from where physicians are readily accessible it is necessary to carry some medicines and a few surgical appliances. The use of these must be understood by the chief of party. The following is a quite complete list and a liberal quantity for 16 men, 90 days:

Medicines and Surgical Appliances.

1,500 Quinine tablets or capsules, 3 gr. each.
1,000 Cathartic pills, triplex (blue mass, aloes and podophyllin).
1,000 Pills, strychnine, aloin and belladonna.
1 Lb. Rochelle salts.
1 Pint castor oil.
200 Dover's tablets, 5 gr. each.
1 Pint Jamaica ginger.
1 Oz. tinct. aconite.
1 Quart witch hazel ext.
1 Pint turpentine.
1 Lb. carbolized vaseline (1 in 8).
500 Corrosive sublimate tablets. Use one for 1 pint water.
4 Oz. carbolic acid, prepared for dressing wounds, instructions.

Medicines and Surgical Appliances.—Continued.

1 Hypodermic syringe, with instructions for its use.
½ Oz. morphia tablets, with instructions for their use:
2 Dozen chloride of gold tablets for injections, snake bite.
½ Pint ammonia, snake bite, animals.
2 Sticks lunar caustic, in boxes, snake bite, animals.
2 Quarts whiskey, snake bite, animals.
8 Oz. collodion with 10% iodoform.
½ Pint sweet oil.
2 Oz. iodoform.
Iodoform gauze, 10%.
1 Box corrosive sublimate cotton.
1 Lb. corrosive sublimate gauze, white.
1 Box surgeon's adhesive strap.
1 Dozen court plasters.
6 Surgeon's needles, half round, assorted sizes.
1 Spool surgeon's disinfected thread, silk.
1 Bot. silkworm gut sutures.
1 Pair dressing scissors.
1 Tenaculum forceps, dressing.
3 2-in. rolls roller gauze bandages.
2 3-in. " " " bandages.
1 Lb. white mustard, prepared for plasters.
6 Bottles P. D. pain killer.
12 Bottles Bull's cough syrup.
8 Oz. sweet spirits nitre.
4 Oz. silicilate of soda.
1 Oz. ipecac, fluid extract.
1 Oz. phenacetine, 592 tabs., with instructions.
4 Oz. normal lig. ergot, with instructions.
1 Oz. 4% solution cocaine, with instructions.
500 Grammes Squibbs Sulph. Ether, with instructions.

CHAPTER IV.

The Preliminary Survey.

The Preliminary Survey of a railroad consists in running such angle lines as are necessary to make an estimate of cost and to determine the route for the located line. An estimate made from a preliminary survey must necessarily be but a rough approximation. It is not desirable to use this estimate as a basis of the correct cost of construction. As a guide to the advisability of a line as a project, a preliminary survey may properly form a basis for an estimate.

When a closer estimate is desired *a preliminary location* is sometimes made, and an estimate of quantities derived from it. Such an estimate is considered to be a closer approximation, inasmuch as the curves are run in, thus giving a truer profile and length of line. A preliminary location, however, does not give a close approximation of quantities, because the center line is not determined with sufficient care. Running in the curves on a preliminary line does not make a located line of that preliminary. Final location is sure to shift the center line so as to vitiate any estimate. Grading estimates computed from a preliminary survey or a preliminary location are therefore of little value. Distance, bridging, clearing and "classification"[1] can be predicted from preliminary surveys.

The legitimate province of the preliminary survey, as the term implies, is finding approximately the route of the located line. The preliminary line is run to condemn or to confirm the conclusions reached by the engineer in his reconnaissance for route. If the pocket instruments carried in reconnaissance have been sufficiently and capably used, the preliminary should not condemn a route selected by reconnaissance. The route should not be impracticable. It may be less desirable than some alternative route. To show how good a line a proposed route will furnish is the proper office of a preliminary line.

For convenience, we shall consider the following cases: (1) When no preliminary is needed; (2) Where one preliminary is needed; (3) Where several preliminaries are needed—the last being the general case. The field methods differ with each of these three cases.

It sometimes occurs in very easy country that no preliminary is needed. In ordinary country, an experienced chief of party, by doing good reconnaissance work, can use but one preliminary line. Often several preliminaries are required for at least a part of the distance. Obviously a difference in the field practice is necessary whether none, one, or several preliminary lines are used.

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[1] "Classification" is often used as being synonymous with rock excavation.

NO PRELIMINARY NEEDED.

Where no preliminary is needed is an unusual condition. On some of our Western plains and in some deserts the ground is level, the drainage direction is constant or indifferent, and the whole region is quite devoid of topographic features. The drainage direction was constant on the Missouri Pacific line from Bald Knob, Arkansas, to Memphis, Tenn. The line lies in the bottoms of the Mississippi River. The high water mark was high up in the trees (26 ft.). The line needed only to avoid striking elbows of overflow drainage channels lengthwise. The drainage direction may be said to be constant on the Southern Pacific line near Salton in Arizona. The line is some 200 ft. below sea level. The drainage direction may be said to be indifferent on the Llano Estacado (Staked Plains) where the Texas and Pacific Railway crosses in Texas. The sand hills are sharp and somewhat high, but the water settles and flows locally to any point of the compass.

It may be here desired to run from a certain point on one edge of the region just described to a certain point on the other edge. The question is merely one of direction. If some plan can be found to enable the transitman to see some object entirely across the featureless region the problem is solved. On railroad work towers are not often used to see across as in coast survey work.

Too many engineers run a preliminary line across, just to get the direction for the located line. Such lines were called Exploration Lines. They were called Spur Lines in Texas. A truer name would have been "reconnaissance with entire party." The chief of party should be able to make a reconnaissance alone, or with a man or two to help him. Exploration lines are expensive, and only justifiable when failure of other methods of long distance sighting is assured. Heat waves and haze are the enemies to long sighting in these southern regions. The morning or evening when the sun is near or just below the horizon avoids the heat waves. The morning air is preferable, however. If the object sighted at be white or bright the sun must be shining or about to shine from the transit toward the object. This makes the evening the only choice when running easterly. The first object to consider for use is a large white flag on as high a pole as is obtainable or on a high tree if available. Set the transit exactly on the hub from which the new direction is to be turned and watch for the flag from gray dawn until a little after sunrise—unless the direction of the line necessitates using an evening sun. Should that fail, try a cylinder or truncated cone of bright tin on the pole. A number of small sheets of bright tin fastened together at different angles and let sway on a pole in the wind will sometimes flash a light to a transit when the above methods fail.

The writer was once driven to the use of this when the cylinder and cone had failed. A setting sun had to be used and, as but a flash is given, constant watching is necessary, and there is some

lottery about the method. Undoubtedly a lantern could be used at night, but it is hard to tell it from a star, and the stars are brilliant everywhere in those skies.

A method used by Wm. Hood, Chief Engineer of the Southern Pacific Company, commends itself. Take a keg of black powder, empty it out on a paper, and fire it on a quiet morning, between dawn and sunrise. Sight the transit at the column of smoke. There must be no wind or the column would not be vertical, or might not appear at all. The amount of powder can be varied with the distance. One keg serves for a considerable distance. This method is, on the whole, probably better than any of the others.

A heliotrope could be used to good advantage where it is possible to elevate it sufficiently. The prohibitive cost of these instruments need not deter one, as a small mirror can be fastened on a wooden frame and set on any instrument tripod, and good work up to a fifteen mile distance be done. Or, assuring yourself of the object to be flashed at by finding it first with field glasses, you can then flash the transit with a small mirror held in the hand. The sun's direction must not be prohibitory. None but those who have sighted at these small mirrors realize how far and how very plainly a mirror a couple of inches wide can be seen. Railroad engineers might well use this flash light more than they do, thanking coast survey engineers for introducing so effective a means. To find the direction for a located line without a preliminary, is, therefore, to be shown by careful reconnaissance to be feasible and then carried out by signaling.

Knowing the one direction for the line—there being no obstacles to deflect for—the work is to preserve that direction and the details of location field work are as usual. It is best to defer their description until we consider the case of making the location when several preliminaries have been run. The case of no preliminaries involves extreme care in using long tangents on flat gradients. A tangent is the hardest line for a transitman to run correctly. While the writer made a good record as a transitman he wishes it known that an absolutely straight line is a rare thing on a railroad center line. Slight swings exist on many summits in America—even where the best of transits and transitmen have been employed. But on level gradients there are no summits to make slight swings invisible, and a visible swing in the rails is always distressing.

ONE PRELIMINARY NEEDED.

In the case where the country is easy, one preliminary will suffice to locate minor obstacles. Follow closely the general direction between controlling points, have few angles and do not try to avoid everything. Run for direction, mainly. Do not deflect for every creek elbow that the line strikes lengthwise. Note the station and "plus" where the preliminary is on wrong ground and the direction and distance to the nearest good ground desired for the line. Nor should the line be deflected when it strikes a short hill or a narrow

valley in a manner not desirable. Note these obstacles together with the differences in the profile which a corrected line would give. The paper location of the located line will readily avoid these bad places, and the approximate estimate for comparison of preliminary lines is readily corrected. Where a single preliminary is run, a good rule to follow with reference to the breaking up of tangents at local obstacles is never to break the tangent unless the time of the party can be thereby saved. Usually it wastes time to break the line. A broken preliminary cannot be followed and checked on as closely by the located line as a preliminary that has its tangents less frequently broken. Neither platting nor computation is as close as actual running. Breaking up or offsetting a preliminary tangent usually delays the party more than cutting out the line. Of course, where one tangent makes a large angle with the succeeding one the angle must not be turned all at once, for to do so would lengthen the line and distort the profile. Except in this case of a broken line forming the chords of a curve having many degrees of curvature, it is wise to use long tangents on the preliminary line which location in easy country is to follow closely.

TWO OR MORE PRELIMINARIES NEEDED.

In rough country two or more preliminary lines are needed, one following each of the several alternative routes selected by the reconnaissance for route. Such preliminaries are not to guide a located line in direction, but to develop a route and to show its relative value for a location. Conform, then, to the topography, use short tangents which shall be chords to long curves on probable location, and in every way make the transit line conform to the grade line the level determines.

There are, then, two distinct classes of preliminary lines: (1) a preliminary in easy country which should have long tangents and keep the direction closely; and (2) the preliminaries on alternative routes of difficult country which should conform closely to the topography, be broken up into short tangents and primarily aim to locate on the ground the grade points which leveling instruments have chosen as points on the center line.

RECONNAISSANCE FOR LINE.

We shall next consider the order in which each step of the party on preliminary survey is to be taken. While the party is getting into camp, equipment being put into working order, and instruments being adjusted, the chief of party must be making the *reconnaissance for line*. To do this he is provided with the map of reconnaissance for route and with the instruments described in Chapter II. Going to the starting point A, he first notes the reading of the aneroid barometer at A. If he knows the correct elevation of A and his aneroid reads *out* in either direction it is probably an error due to atmospheric conditions. Note the reading, error, and time of day. If the elevation at A is not known but assumed, as already

indicated, set the aneroid at the assumed elevation of *A* by turning its movable circle, which is graduated in feet, so that the barometer now reads at *A* exactly that elevation in feet which *A* is assumed to be. Repeat this observation at *A* carefully for several days when the barometer seems stationary and carefully determine that your setting of the movable circle is correct at *A* for that assumed elevation in feet. The aneroid now reads as your profile elevations will read for this survey. Carefully note at what inch and decimal thereof the zero of the movable circle is set when that movable circle reads correctly at *A*. During the progress of the work, close watch must be kept that this zero does not shift around the fixed graduation in inches, as it may do on horseback.

Having noted the elevation and time of reading at *A* see what two points ahead and some distance apart are in the direction of the line *A a,* as shown by the prismatic compass. Ride toward those points, keeping your horse always directly in line with them. Never try to ride directly toward one point only. It is impossible. None but a novice would attempt to do so. Remember that you are riding on a proposed transit line, and that your horse's track should always be visible to the chainmen, as the transit lines the chainmen in. Ride always with spurs and a steady rein and your horse will after a time form the habit of never turning of his own accord and never drifting off sidewise. Just before reaching the first of the two objects taken from *A* as being in the direction of the line *A a,* note a third object in line with the first two objects and some distance beyond the second. Thus keep at least two objects ahead of you which are on line. So proceed until you reach the top of the first ridge. Here, standing at the object which marks the last point which could be visible from the rear, you take a reading with the prismatic compass to show the direction of the line *A a,* and note on it two points or objects ahead of this ridge which shall be on that line. Ordinarily you can get a point on the next ridge and one in the valley between the ridges, together with two or three intermediate points, so that you ride from ridge to ridge by points already selected. Still, the principle holds of always ranging yourself in by two points ahead of you which have already been determined by the prismatic compass.

As you ride you note the direction and character of the drainage. Whether you sketch it on paper or not you must get a map of it in your mind so that it may be said figuratively that the drainage map is so etched on your brain it cannot be effaced until the located line has passed beyond the point now being studied. To know the effect on the relation of the drainage to the line, produced by shifting the line to right or left, is very important. The aneroid is read at each valley and ridge of importance, always noting the time of observation as well as the apparent elevation in feet.

Topographic sketches must be made to guide the assistant, who is to find the line for which reconnaissance is being made.

These sketches show a description of the initial point A, the bearing of the initial tangent, its approximate length, and the angle between the first and second tangent, correct to the nearest reading of the prismatic compass. But this is not by any means sufficient. The sketch must show the drainage in general and very correctly along the line so that the assistant can see that he is on the ground chosen. Trees, bushes, rocks and elbows of streams are best to show this. If it be a prairie country, the writer has used a "*horizon*" to show the assistant where the line should cross a ridge. By a "h o r i z o n" is meant a profile of the outline of the next divide as it a p p e a r s against the sky. Its object is to show the assistant where the angle he is turning, for example, at Q, Fig. 14, should cause the transit line to cross the next divide as at R. The object is twofold: (1) to reassure the assistant that he has turned for the right point; and (2) to give a closer approximation of the right line than can be had from a prismatic compass bearing. If a bush, or a rock or tree shows on the "horizon" exactly on the desired line, or if the outline against the sky has well defined features the exact point can be shown by the horizon. Where timber or brush interferes with showing the horizon by a sketch, then the point R must be "*flagged.*" By this is meant tying a strip of white cloth an inch or two in width to a prominent bush or tree limb. If this be tied at as great height as is convenient when sitting in a saddle it will not be disturbed. After a little use the eyes of the party will detect them, and if not close to the transit line the offset can be paced and the flag located on the map. Where many flags are used and the party is close behind, marking the letter on the flag with red or blue pencil which corresponds with the letter on the sketch is useful. Where more than one preliminary is being run in the same route, flags of different colors or combinations of colors readily distinguish the different

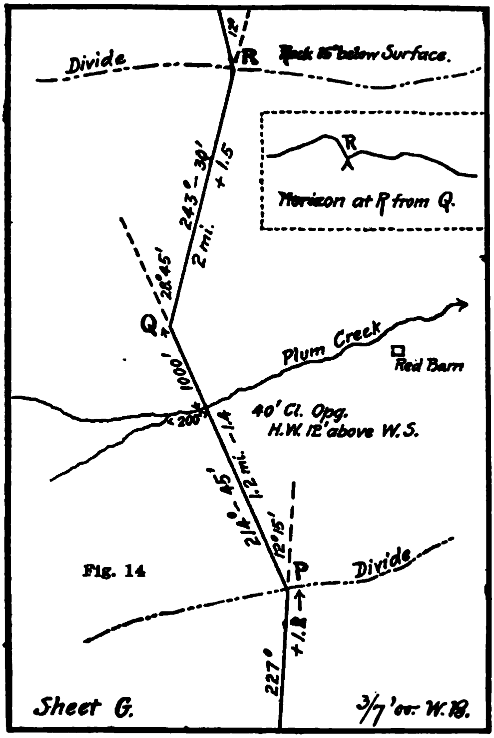

Fig. 14

lines from each other. Such flags are almost indispensable in brush country. The writer finds that flags save time and allow closer work to be done in timbered mountainous country. There the flags must be marked in letters to correspond to the point lettered on the sketch, because some flags may be passed. Not even using flags of red and white for angle points and white flags for range points can prevent blunders, as experience has shown. Sometimes a red flag against the sky as a background is better than a white one. In winter a white flag is unsafe, as a snow background makes it invisible. On unsettled prairie flags are useless. Where the country is settled and fences or hedges obstruct the view, tie the flags to them if needed. Flags are most useful in brush, are valuable aids in timbered mountains, and if they were used generally in timbered country there would be much less backing up of transit parties and much less censuring of assistants for failing to find the line reconnoitered. When the writer was a levelman on preliminary survey he kept well behind the transit in rough timbered country until almost night, because by so doing he did less work by giving the transit plenty of room to "pull back" through having missed the route. A chief of party should so make and flag out and sketch his reconnaissance for line that his assistant can readily find the line. Neither the levelman nor any other member of the party should have a chance to sit down while the assistant is "looking up the line" which the chief of party has omitted to mark clearly.

Any instructions necessary to be given, in addition to the sketch, should be written on the sketch. No sketch to scale is practicable. With an experienced assistant terse cabalistic topographic signs can be used, easy to draw and clear in significance. The writer found it useful to make these sketches and the field marks on flags in blue pencil. No other blue pencil was allowed on the party. When the assistant made a sketch or notations on existing sketches he used the only red pencil allowed in camp. The color of a mark had its significance to the party and there was no confusion or divided responsibility for it.

The work on reconnaissance for line prior to the beginning of transit and level work is of great importance. The men who do such work have written little or nothing of it. It is hoped that the rather condensed explanation of the objects and practical methods of the work will prove to be clear and concise.

TRANSIT WORK.

The chief of party may start the party at work the first day, but as he should be as a rule on reconnaissance work, we shall assume that the assistant only goes out with the party. With the sketch, just described, for his guidance, he starts for the initial point *A*. He goes from camp with his party in the line wagon, together with all line tools and equipment, stakes, lunch, water-keg, etc. Arriving at *A* the transitman sets up the transit on it, backsights along

the line shown on the sketch, turns off the angle as ordered by the assistant and shown on the sketch.

A transit should be adjusted very carefully under favorable conditions and then its adjustments should be let entirely alone as long as possible. There is but one way to lift a transit out of a box —that is by putting the hands under the plate. You may carry it in the box or in your lap on a spring seat. There is but one way to carry it on the shoulder—balanced on an under leg on the shoulder blade, your hand grasping that leg and the plumb-bob in your pocket on that side. In sighting move the cross hair up slowly and never go by. One good sight is enough for a point. Never dilly-dally with a sighting. If your eyes are dim or your resolution weak do some other engineering work. You are, and always will be, no instrument man. A good instrument man is a man with engineering knowledge and the mechanical faculties. One of the most accurate transitmen the writer ever saw was so irresolute and took so many sights that he materially increased the cost per mile of location. Another transitman, still more accurate in his work, was the most rapid transitman the writer ever saw on a locating party. Be careful, think what you are about, look closely, and go ahead.

Except on very rough ground always set the tripod so that one tripod leg stands on the forward line of sight. This gives room to stand at the transit between the two other legs of the tripod and move the feet comfortably without fear of touching the tripod legs. Assistants and chiefs of party often forget that transit running is tiresome, ceaseless work. The old idea of putting two tripod legs on the down slope is fallacious. If the slope be steep enough to make it necessary it is steep enough to make it impossible to get the third leg deep enough into the hill readily to level the tripod head. Students or young men who wish to become transitmen should practice closing either eye so as to use the eye that the sun does not shine into. A transitman should use about 1,200 ft. sights as a maximum, using a front and a rear sighting rod of about ⅝ inch in thickness, covered with strips of cloth, alternately red and white. The plumb-bob must be small in diameter and long to give weight. The string should be as fine as will safely carry the weight.

CHAINING.

After the rear chainman has steadied and sheltered the plumb-bob to aid the transitman in setting up, he throws out the chain in the usual way. The length of the link chain from out to out of handles is 100 ft. The stakeman walks along the chain when the chainmen have it nearly on line to see that no rings or loops are kinked and that no link has suddenly been bent, if a link chain is the kind used. Beyond all doubt a ribbon chain is superior to any link chain. As the transitman gives the head chainman "*line*"[1] the rear chainman

[1]Lines in the rod held by the head chainman.

stands in front of the transit and holds the rear end of the chain on the tack under the plumb-bob. The chain must be pulled taut. The amount of pull must always be the same, and it is best to pull about all that two strong men can. Slack chaining will never do. In level country it is best to chain with the chain lying on the ground for its whole length. One head chainman, on one of the parties worked by the writer, chained on level ground with the rear end of the chain at the height of the top of the stake and the head end of the chain a little farther from the ground, but slanted the point of his rod ahead an amount experience had shown him would put the point of the rod 100 ft. from the bottom of the last stake. Such chaining is hazardous. This man began it long ago when none of us were chaining as closely as now. By having strong and careful rear chainmen, and by taking great care to have the tension of the chain and the slant of his rod constant, his results were all that could be desired. The most important requirement is that the chain should be kept practically level. "Breaking the chain" on rough ground is always too little done. Fifty foot or twenty-five foot lengths are used as a rule far too little. Compute the error you make on the slope you are on for each 1,200 ft. sight and you will often find that you cannot afford to allow any such errors as you are making. It is absolutely useless to put a good transit in the hands of a capable transitman and then allow such chaining as most locating parties do. The accuracy of the chaining and the closeness of checks in distance is one test of the head chainman's fitness for this position. With most of our present chaining it is idle to center a transit on a tack and bisect a rod in setting a forward point.

STATION STAKES.

After the head chainman has measured the first hundred feet and has been lined in by the transit the first stake or "station" is driven and marked "1." Usually, on preliminary, stakes are set not oftener than at 200 ft.—some at 500 ft.—intervals. This is where stakes must be transported some distance. A stake must stand driving well, must be such that it can be marked very plainly, and should be readily seen. Split stakes, planed on one side and without sap wood, are therefore desirable. A stake must be driven plumb, firmly into the ground and be long enough to leave at least length enough out for marking. Stakes should be marked so that numbers read downwards, with a heavy lined round figure like most stencil figures. The lines should be gone over several times, so that when the color is gone the fiber of the stake still shows a rubbed greasy mark. Probably the best material to use in marking is a form of crayon. A crayon made of well ground material assures uniformity in the crayon and avoids those hard spots which will not mark at all. Chalk in bulk is not so uniform nor convenient. Red is the color used—save where other colors are desired to distinguish intersecting or neighboring preliminaries.

HUBS.

Arrived at the end of the run, usually about 1,200 ft., the head chainman selects a place where the transit point can be taken. The transit point or "hub" should be selected so that the rod should be visible from the transit to within a few inches of the ground. Of course this means visible as a back sight or fore sight. The head chainman signals[1] the transitman that a point is to be taken. The transitman should turn his telescope upon the back sight, assuring himself that his instrument has not "swung off." Never take any sight forward after receiving a signal for "point" until you have assured yourself that your transit is on line. Young transitmen always make this mistake and many old ones are not much freer from it. No good transit will stay closely on line as a rule. Cloudy, quiet days make an exception. Having checked the transit on back sight, set the front rod on line. Then the "hub" is driven of such length that hard driving is needed to leave its top an inch out of the ground. A hub is the permanent monument that fixes the preliminary line, perhaps for years before the line is used. It must be driven deep into the ground, without brooming the top, and be of wood least liable to decay. After driving it a point is taken on it with the rod, which the transitman lines in. The transit is now unclamped in its upper movement, turned 180° on its vertical axis and sighted on the back sight rod. The telescope is revolved on its horizontal axis and a second point taken by the front rod on the hub just driven. If the sighting is correct the distance apart of these two points on the hub is twice the error in the adjustment of the cross hairs of the telescope. This procedure is precisely the one followed in adjusting the cross hairs. It is also called "taking double centers." Therefore place the tack midway between the two points taken on the hub. If the distance between the points on any hub varies from that on preceding hubs, the head chainman will know at once that an error has been made—probably in sighting. He signals to the transitman to that effect and another pair of points are taken by repeating the process. No other plan insures such check on errors of sighting the telescope or holding the rods. It is wise to keep fore sight and back sight distances of the same length. On rocky ground, and sometimes in ground thoroughly frozen, it is impossible to drive a hub so that the top is level. Rods cannot then be held on ordinary tacks. An indented tack can be had from instrument makers in which the points of the rod will be held. These tacks are of value, economically, and give greater accuracy as well. A numbered witness stake is driven one foot to the right of the hub, and after driving the tack the transitman is signaled by the head chainman to come ahead. The transitman signals the back flagman, and the chainman and axman must wait for these two men to

[1]The signal usually consists in holding the rod horizontal above one's head.

reach their advanced points. That this wait must occur for each transit sight makes it imperative in the interests of the company that no trifling boy or lazy man be back flagman and that no transitman be employed, whatever his other qualifications, unless he has sufficient size, strength and stride to carry a transit rapidly and easily over all kinds of ground through all kinds of weather.

TRANSITMAN'S NOTES.

The transitman's notes show the station and plus of the transit points, the needle reading of each course, as a check to angle readings, and a record of the size and direction of the angles. His notes must show dates of work, time of beginning and quitting each day, and a note must be made of the weather, especially as regards sighting. A party cannot stop for poor sighting, but it is best to know where an error is to be sought for in case work does not check out later. In short, the transit notes are complete alinement notes only, with such information as fixes the location where bad work is most likely to occur. It is the duty of the rear chainman to shield the plumb-bob and its string from the wind and center the bob for the transitman in setting up. He must keep check on the correct numbering of the stakes. The rear end of the chain is the only end that should ever lie near the transit.

It is the duty of the head chainman to select the transit points save where angles are to be turned. Such angle points the assistant must indicate. When the transitman moves up it is the duty of the assistant to name what the direction of the angle and its amount or direct toward what object it should be turned. Too often angles on a preliminary are turned to odd minutes or an awkward part of a degree. This is not necessary in easy country, and is a scholastic refinement foreign to good railroad work. Always remember that the transitman is the hardest worked engineer on the party in the field and often does the hardest work in the office. Therefore avoid bad splitting of degrees and odd plusses at transit stations, as far as possible.

TOPOGRAPHY.

The assistant takes all the topography. He should seldom be obliged to go ahead of the head chainman. No rule as to the width of belt of country covered by him in taking topography can be given. The preliminary topography must be all that is necessary to enable the located line to be put on paper. The assistant will fail to do this at some points. This must be expected and the chief of party must supplement the work there. Of course the danger is that he will take too little topography. Sometimes the assistant takes none. There are tons of topographic note books in the United States which are almost blank paper. Western lines have been largely run this way. Many engineers, especially in the East and often from European schools, have used several men on a party taking topographic measurements and notes in moderately difficult country. Thousands of dollars

have been spent taking slope notes which were little used or never looked at. Engineers often take them because they might need them. Between these extremes, meager topography on the one hand and voluminous topography on the other, it is likely that the golden mean lies. It does not seem probable that office engineers or teachers of engineering will ever settle the question for locating engineers of our railroads. To the latter topography is a means, not an end. When needed it must be accurate and just sufficient. Outside of that it is an expensive waste. It takes almost as good a man to see what topography to take and what to let alone as it does to make the reconnaissance for the line. The topographer who uses a line in his note book for every 100 ft. of line is not the right man. He may use but one line of his note book for a mile and be doing the best work. He may need a line for 10 ft. He may consider the half distance from center to side of page to be 5,000 ft. or 50 ft. Engineering judgment must tell him how much and how little topography to take. Of course in the organization outlined he must keep up with the chain party. At times the assistant needs a man to assist him in taking topography. He must show all drainage, all change in direction or degree of slope, and note the rate of slope when the rate changes; land lines, clearing, distances to obstacles or improvements, and in short all things to be met by any likely change in the present line. The pocket instruments he uses are a small compass to locate distant points by bearings from two stations; a hand level to be sure of rates of slope occasionally and a rectangular protractor also used as straight edge and square in sketching. All field notes must be taken with pencils so hard that notes will not blur. HHHH drawing pencils are about the right degree of hardness. Instrumental notes should not contain erased figures. Cross out errors and write in corrections near erroneous figures.

LEVELING.

The levels are more important to the operating department than the transit line. Civil engineers have given too much heed to alinement and too little to gradients in the past. The level is not secondary. To run good levels and "keep up with the transit" is impossible on some parts of most lines. This vicious old habit has caused many well intentioned young levelmen to do much poor work through false pride and foolish counsel. For good work, ordinarily, the lengths of level sights should not exceed 300 ft. In bad weather for sighting or in heat waves this distance should be decreased. In leveling, the fore sights and back sights should be equal. It is safer to depend on this than on perfect adjustment of the level. In practice, old levelers sometimes run with their "level out;" and if the country be undulating they keep the *sum* of the fore sights equal to the *sum* of the back sights between consecutive benches. This is hazardous, but allowable on preliminaries. It is a general rule to depend not on perfect adjustment of a transit or a

level for good work but on the equalizing or compensation for errors—hence equal sights. Never adjust either transit or level during the hours of work unless an accident occurs to the instrument. When the level gets out of adjustment keep each fore sight equal to its back sight and so complete the day's work. The morning is the best time, usually, for adjusting an instrument. The air is better for sighting, the sun does not disturb and the wind is less strong. Adjusting pins belong in camp. They should be carried on the line for emergencies only, and carried by the assistant.

The description and elevation of some initial point for the levels is given by the chief of party. This must be well "referenced"[1] in the field and described by the levelman in his notes. Permanence and definiteness are desirable. As the rodman stands behind the rod to set the target for a sight he must endeavor never to pass the height of the cross hair, that is, "go by." This is the worst early fault of rodmen. The rod once clamped at the supposed right length it must be "waved" or "rocked" toward and from the levelman. This must always be done on turning points. The rodman "calls out" the rod reading on all turning points and records the reading in his rod book, where he carries along the heights of instrument and elevations of all turning points. The rod is read to hundredths on turning points. The rodman holds the rod upon the ground at each station—usually "so as to cover the figures," i. e., close behind the stake or at some place nearby where the usual spot does not correctly represent the level of the ground for that station. The rod is read to tenths of a foot at stations and for all other ground readings. As the rodman passes the levelman he should repeat the height of instrument shown in his rod book, checking the levelman. When three hundred feet or less beyond the level he signals for "point," and if the levelman assents he drives a "peg" on which to take a turning point. These pegs are just long enough to be solid in the ground and large enough to drive without brooming. A reading is taken, as on the initial point, and the levelman "called up." The rodman repeats to the levelman as the latter passes the elevation of the turning point as shown in the rod book. The object is to avoid carrying errors by checking of the two men on each elevation. The levelman should look at the rod reading on the rod if he cannot read the feet and tenths through the telescope. The rodman should read the rod before and after recording each reading in his rod book. Eternal vigilance is the price of errorless rod reading.[2]

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[1]Measurements and bearings to natural or artificial reference points must be taken and recorded.

[2]What constitutes "good levels" for railroad preliminary and location is a point engineers do not view alike. Herewith are the errors made by an excellent young engineer with the writer's party in the first levels he ever ran on location work. It was in the Ozark Mountains in 66 feet country. The level bubble was not very sensitive—to aid speed. The rodman was a first class man, of long experience. The levelman had difficulty in keeping up on preliminary at first, but had ample time on location. The transit party

BENCH MARKS.

A bench mark is the monument of levels. Undoubtedly, it should be a natural object, such as a tree or a rock. All are familiar with the typical B. M. on a tree root;[1] but throughout the most of our land trees and rocks do not exist or are so infrequent that bench marks are too far apart when placed upon them. Without discussing what all might not agree upon, it suffices to say that bench marks must be as permanent as possible, well defined with reference to the line, and close enough together for use in the construction of the line without auxiliary bench marks. The writer prefers a hub bench mark at least 2 in. square, 15 in. long, driven to within one inch of the surface of the ground, a round headed tack in it, and a witness stake by it. These are to be placed on the right of the line twenty-five paces from and opposite to each twenty-fifth station, save where the ground forbids. The elevations are seldom marked upon the benches, for chalk marks will become dim. It is asking too much of a levelman to expect him to check his notes completely at each bench mark. His office check by sum of fore and back sights is better. It is best, when time cannot economically be taken to put in bench marks so closely together on preliminary, to put them at fifty-station intervals, and then interpolate bench marks on location. In timbered country the benches must be put closer to the line on preliminary, and the stakeman or rear chainman should cut them on trees, but these trees must always be off the right of way. In difficult country, the transit hubs should frequently be used as turning points.

High water marks are very important and justly take much of the levelman's time at crossings. The elevations of outcrops or rock ledges must always be noted.

DRAFTING.

The office work is often done by the field party at night. This is undoubtedly not the best plan. There should be a

was an old and a fast one. These errors between the preliminary and location benches is about what may be expected under the circumstances. Levels should be as good to be satisfactory.

PRELIMINARY AND LOCATION LEVEL DIFFERENCES.

Station.	Divergence.	Error.	Station.	Divergence.	Error.
218	—0.29	—0.29	2302	+0.91	0.15
604	+0.09	0.38	2410	+0.97	0.06
1024	+0.25	0.16	2512	+0.97	0.00
1160	+0.30	0.05	2720	+0.95	0.02
1316	+0.39	0.09	2841	+0.93	0.02
1638	+0.57	0.18	3063	+0.84	0.09
1735	+0.69	0.10	3186	+1.09	0.25
1878	+0.72	0.03	3558	+0.98	0.11
2118	+0.76	0.04	3870	+1.08	0.10

Average error per 100 Stations = 0.028.

[1]A pyramidal shaped projection (made with a hatchet) containing a nail driven flush with the wood.

draftsman in camp to complete the office work. Working field men until ten o'clock each night platting their notes of the day is of doubtful economy. But the entire field work of each day must be platted in outline by someone before the chief of party sleeps that night, and *all* the platting for one day's line must be completed within the twenty-four hours following. If there be no draftsman the day's work must all be platted by the field men before retiring. The transitman plats the center line by tangent deflection, the topographer doing the very large scaled maps for him. Many engineers use long rolls of paper. Sheets are better. Good manila paper is all that is required. The scale of this map must vary with circumstances. In easy country the writer used 1,000 ft. to 1 in., supplementing this by a special map of 100 ft. to 1 in. at the difficult points of that line. In difficult country 1,000 ft. to 1 in. is valueless for a preliminary map. In mountainous country 100 ft. to 1 in. is too small a scale and 50 ft. to 1 in. has to be used. Sometimes 20 ft. to 1 in. is used for a short distance.[1] In general, the scale of the preliminary map should be just sufficient to show what is desired at the ordinarily difficult points of the line the map covers. The tendency is to use too small a scale, although some few engineers seem to err in using too large a scale.

The transitman should call off his line notes, looking up the tangent deflections for the draftsman to plat the center line.

In platting the transit lines where several preliminaries occur the first preliminary (A line) is drawn in red ink; the second preliminary (B line) is drawn in blue ink; the third (C line) is black ink—each line on the map having the same color as the marks on the stakes. The first preliminary is left in pencil. Another reason for using colored inks on maps and profile is the greater ease with which the eye can follow and estimate the relative work, length and grades. It is like separate maps and profiles on tracings which you superimpose at will on each other. An outgrowth of this system of colors for preliminaries was that the men dropped the words "second preliminary," "C line," etc., and spoke of the blue line, black line, red line, etc. The engineers were inclined to the same nomenclature for field work, but supplemented it by the letter as "yellow or D line." As an engineer should always strive to save distance it is recommended that any later preliminary adopt the initial number of the station of that earlier preliminary from whence it starts. As this latter line usually ends on the same line it strives to improve, the difference in distance by the new line is shown on the stakes and is a plainer fact to be seen.

The assistant next plats the topography for the day, at the critical points. This completes the mapping for the day.

[1]Mr. Wm. Hood, Chief Engineer Southern Pacific, uses a scale of 50 feet to 1 inch for preliminary maps.

THE PROFILE.

Check the level notes by finding out whether the difference between the sum of the fore sights on turning points and sum of the back sights on turning points is equal to the difference in the elevation of the first and last point in the day's work. Then the levelman has the rodman read the stations with their elevations and plats on profile paper all the level notes taken during the day, using inks whose colors correspond with the transit line. Engineers naturally differ as to the proper scale of the profile. We are all creatures of circumstance, and as the writer began railroad work on the Texas and Pacific Ry. he prefers using Plate "B," as known to the trade. The vertical scale is 1 in. to 30 ft. and the horizontal scale 1 in. to 400 ft. The Southern Pacific Company uses this same scale, and it appears to be common in the West. In the Mississippi Valley, Plate "A" is used, i. e., a vertical scale of 1 in. to 20 ft. and a horizontal scale of 1 in. to 400 ft. It seems that most Eastern roads use this scale for profile. It is best to become familiar at the start with one or the other of these scales for profiles. Changing involves much loss of ability to judge the amount of grading per mile by glancing carefully over a profile of the line. While not wishing to be opinionated in the matter, the writer, after long discussions, believes in the use of Plate "B" profile paper for all preliminary or located lines. For a construction profile or a record profile Plate "A" is better.

As the preliminary line usually has a stake every 200 ft. the levels are taken that distance apart. All heights taken are platted, including all high water marks and all elevation of rock out-crop. Each tenth station number is marked on the profile at the top and the lines of the profile, giving an elevation of full hundred feet marked each one hundred stations. Names of streams are written vertically on the profile, high water marks and notes as to size of clear openings marked on profile and the work of the levelman for the day is completed.

The chief of party now lays the grade line on this profile. It must be laid so as to furnish a fair basis of estimation of cost of this preliminary with others. Some general considerations of the principles which govern that manipulation of a black silk thread on a profile known as "laying the grade" must be stated here. The general idea is to so lay the grade that the "cuts" will make the "fills."[1] Usually this makes the least number of cubic yards of grading. Fills have a slope ordinarily of $1\frac{1}{2}$ to 1, i. e., $1\frac{1}{2}$ horizontal to 1 vertical, and the roadway is 12 to 18 ft. wide for single track. Cuts, however, often have steeper slopes and wider roadways—usually 1 to 1 slope and 16 to 24 ft. roadway. For each road the cubic yards per station for some center height of fill will just equal the cubic yards in the

[1]That is, the excavation will make the embankment.

same center height of cut. For example, on many of Mr. Gould's lines there was used a 14 ft. roadway on fills and a 1½ to 1 slope, and in cuts an 18 ft. roadway and a 1 to 1 slope. Now the cubic yards in one station of 100 ft. for a 6 ft. fill equals the cubic yards in 100 ft. of 6 ft. cut. Therefore cut and fill were equal in 6 ft. work. This fact must be learned for your road and that equivalent height of cut and fill be fixed in your mind. For less than this equivalent height either the cut or the fill will exceed the other for equal center height. For more than this equivalent height of cut or fill either the fill or the cut will exceed the other in cubic yards. After some practice one makes these allowances unconsciously. It is not always that laying the grade is so simple as to make the fills balance the cuts, and the cost of each per cubic yard the same. If cut costs more than fill then the equivalent height must be changed. If there be rock the grade must be raised to be economical. For many reasons when a grade line is changed at all from that position which makes cost of fill and cut the same the grade line is raised. Cuts are more expensive to maintain. When in a hurry on Western railway construction we always move the grade line up above where economy otherwise placed it. Said a celebrated construction engineer once to the writer: "Whoever saw grading stop track laying on a fill?" A novice will most likely lay his grade line too low at first. Custom fixes the minimum length of maximum grade to be put in—1,000 ft. is a common minimum length. Avoid level grades in cuts, and generally avoid long shallow cuts. It is the practice to break from a stiff rising to a sharp falling grade by an intervening level grade of a few stations. It is well to do so on a preliminary profile. But on location always run grades together and round off with a vertical curve. To change from even a 1% grade to a level 0.0% will break car couplings. Avoid banks under 2 ft. in height for long distances. It will not drain track and if made from borrow pits is all soil and usually a poor roadbed.

But a most important factor in laying grades is high water marks. All visible water marks are taken by the levelman and are now on the profile. The topographer should have had added data. The chief of party must know the high water record of the country. Of course a grade line must stay out of the water. Engines have waded in 2 ft. of water in the Mississippi bottoms, but steam cannot be made when water enters a fire box. It is a rule that a grade line should be at least 2 ft. above high water marks. In long overflowed bottom crossings this is reasonable. For short distances less will do. But where there is a strong current and the water is bound to "pile up" on the upstream side of the embankment before it relieves the head through the bridge openings 5 ft. is really required. For span bridges it will not do to let the bottom chords touch the water. Hence where such truss bridges occur 5 ft. is the working height needed. The underlying principle is that the bottom of the tie must have more embankment between it and high water than will "soak up" and commence to "churn water," and that bridge

members must not be in the water. Where heavy drift logs or trees run during freshet seasons sufficient added height must be given the grade line to allow safe head room for such drift. It is not necessary to say that we must take some chances of flood waters of unusual heights. It is not economy to build a railroad for record breaking floods. The interest of the money so wasted would renew and pay for delay too long before the record breaking flood occurred.

OPENINGS.

Having laid the grade line on the profile of the day's work on preliminary survey the chief of party must mark the kind and amount of bridging required at each drainage crossed. The levelman has, of course, noted the plusses to the edges of channel and also the amount of clear opening (i. e., distance between foots of slope at pile and trestle openings). The topographic notes show the kind and size of openings at each drainage crossed. Conferring with the topographer the chief of party now marks the opening on the profile. Observation, long experience and careful judgment are needed, and without it formulas will not save from blunders. Experience cannot be gained from reading this or any book—judgment cannot be "read up on." But how shall a man decide upon openings without long experience. It is best for him to start by helping as levelman or topographer some chief of party who has had the practice. Said one old chief of party: "Keep your toes of slope out of the water (channels)." In uncultivated country in Arkansas four acres of drainage area of the usual slope require one square foot of opening. In Northern Texas five acres, and in Kansas six acres require one square foot of opening.

The writer believes these rules of practice in laying grade lines and in deciding openings sufficient. Formulas must be dropped when they are mastered. Who has time to compute openings? What use is there in computing opening on an estimated drainage area? Would you make a survey of drainage areas on preliminary lines? What railroad company will allow it to be done even on location? We are writing on field practice, and it is the purpose to say how to start, how to go on and how to get through, in rational time and at reasonable cost. The slope of the drainage area toward the opening is a strong factor in the problem. Cultivated ground takes up more rainfall and therefore less water reaches an opening. But drift from cultivated fields clogs small openings and often makes them impracticable for any size of drainage area. Always put an opening wherever nature has one. On overflow bottoms, where nature uses an overflow channel beside the main channel, respect that overflow channel and *leave it open.* And on fills standing in heavy overflow put a pile opening, even if small, every 1,000 feet. The amount of opening must be right, but the head of water must be avoided by distributing that opening at frequent intervals. Kut-

ters' Formula for size of openings is good—if you need it. Myers' is just as good, and simpler. It is:

$S = C\sqrt{A.}$
S = area of opening in sq. ft.
A = drainage area in acres.
$C = 1$ for level or slight slopes, $C = 1.5$ for hilly country.
$C = 4.0$ for mountains.

It now suffices to say that when the chief of party has laid the grade line on the profile of the day's work and the topographer has completed his work on the map a study can be made of the line for the day. If the reconnaissance has been properly made and the sketch given the assistant carefully followed there is very seldom any necessity for "backing up" by reason of the bad showing of this study. It must be expected that at some points the line is too far to the right or to the left, too high or too low, or an angle not turned quite where it should be. It may properly happen that a tangent must be broken up to lighten the profile, for preliminary tangents in easy country must be few in a day and long ones. It may properly happen that at some gorge or spur the profile demands lighter work at the expense of a more broken alinement. The chief of party writes these running comments on both map and profile, conferring at each point with the assistant and asking questions of the levelman and the transitman where they might be supposed to give aid or information. For, a locating party, like a general's staff, is the eyes of the chief. The rodman or head chainman can often add to the fund of information, and sometimes axmen or teamsters can do so. It is best to draw no lines on map or profile, but write notes merely. The chief of party has already given the sketch for the next day's preliminary running to the assistant. The entire work of the day is now done.

We will assume that after several days' running a point is reached where the country changes or a point occurs which plainly controls the location. We will assume that the camp has not been moved, as line work is still not too far from camp. Should other preliminaries be run for all or a part of the way? The general considerations which will decide whether more than one preliminary is necessary have been stated. As a rule if this first preliminary from the initial point to the first controlling point be direct in its course, with moderate grades, and averages a low cost of construction per mile, no second preliminary is economical. The first preliminary should be the shortest one and other preliminaries serve to show what can be done toward lighter grades and decreased cost. This is a result of observing the rule: Never depart from the straight line between controlling points except where there is abundant reason for doing so. An unnecessary detour in a first preliminary is an unpardonable error or a want of courage. If the reconnaissance has been properly made and the first preliminary

properly run a second preliminary should be necessary, if at all, for the purpose of cheapening the cost of the line. Bear in mind that this is its proper province.

If it seems desirable to learn at what cost of increased distance —curvature—the cost of construction or the gradient can be lessened, how shall this preliminary be run? It is best to run all preliminaries needed in a region before leaving that part of the line. Solve the problem in hand before taking up another. The notes of the reconnaissance for line by chief of party and made for the second preliminary can be placed on the maps of the first preliminary. These sheets are carried to the field by the assistant in running the second preliminary.

It may happen that offset distances from given stations of the former line, will be the critical points on the second preliminary. The field work is done as in the first line. Each stake or reference mark must have a letter as well as a number so as to distinguish the second preliminary stakes from those of the first preliminary. The stakes may be marked thus "B 2743," i. e., the second letter of the alphabet shows that it is a second preliminary and 2743 is the station number. If the second preliminary starts at station 2520 of the first preliminary then on the reverse side of the stake marked 2520 the mark B 2520 is placed and the next station of the second preliminary is marked B 2521, etc. As an added precaution and aid to quick identification of preliminary lines from each other different colored chalks are used where several preliminaries occur between the same two controlling points. For example: a stake marked *in red chalk* 2744 means that it is 2744 stations of 100 feet each from the initial point on the first preliminary. A stake marked *in blue chalk* B 2744 means that this is the corresponding stake on the second preliminary at 2744 stations from the initial point. A stake marked in black pencil C 2744 means a like stake on the third, and a stake marked in yellow chalk D 2744 means a like stake on the fourth preliminary. Where, as at an intersection, a point is common to two preliminaries, the reference stake is marked with the letter and color of the earlier line on its face and the letter and color of the intersecting line on the reverse side of the stake. Such conventions are valuable aids in difficult timber country and save much time, annoyance and liability to error. In platting the transit lines where these numerous preliminaries occur the second preliminary (B line) is drawn in blue ink, the third (C line) in black ink—each line on the map having the color of the marks on the stakes. The first preliminary is left in pencil. On the profile each ground line is drawn with the same color as the stakes are marked with. Another reason for using colored inks on maps and profile is the greater ease with which the eye can follow and estimate the relative work, length and grades. It is like separate maps and profiles on tracings which you superimpose at will on each other. An outgrowth of this system of colors for preliminaries is that the men drop the words "second preliminary," "C line," etc.,

and speak of the blue line, black line, red line, etc. The engineers are inclined to the same nomenclature for field work, but supplement it by the letter as "yellow or D line." As an engineer should always strive to save distance it is recommended that any later preliminary, adopt the initial number of the station of that earlier preliminary from whence it starts. As this latter line usually ends on the same line it strives to improve, the difference in distance by the new line is shown on the stakes and is the plainer to be seen.

The comparison of the preliminaries between two controlling points will be treated in the chapter on location. This present chapter contemplates that the chief of party shall so thoroughly traverse and study the entire belt of country possible for the line that he does not leave unsurveyed a better line than any of the lines he has surveyed. Engineers who advocate office location from preliminary surveys lose sight of the fact that to find a good line and recognize it as such is the highest form of art in location. That is why a locating engineer must be a field and not an office man. An office man can choose between two preliminary lines found—he cannot insure the company against passing by much better lines the field party failed to find. Of course, office location has its use. All needed preliminaries being properly compared and the best one selected the chief of party should make an office location station by station with the map and profile in his hand as he is walking over that best preliminary. A good locating engineer can make a good paper location with the ground under his eye. This is an office or a paper location. There is no other person, no other place and no other time for an office or a paper location. This somewhat anticipates this point in the succeeding chapter, but it is a point that needs repetition. We have had in years gone by men who used a preliminary line merely to develop country, not as a basis of location. We are now having engineers who use a preliminary as a basis for a topographic map, on which to locate their line in a distant city office, by a man who never saw the country. Between the Scylla and Charybdis the railroad locating engineer who is a topographer, a student and a plain railroader must find his footing.

Before closing the chapter on preliminaries let us define by one or two examples what direct lines are and what they are not. A direct line in one class of country may not be so in another. Engineers will differ, of course. But the writer in giving these instances of his own work can convey better his application of the term *direct* or *straight* as applied to survey.

From Carthage, Mo., to Stockton, Mo., there was a wagon road laid out by commissioners in 1851. Both towns are county seats. The road was made as direct as possible. There were no farms to interfere then. The country is easily rolling prairie with several streams to cross. The measured and recorded distances (in miles, poles and links) is 45.9 miles. The located line was 47.0 miles long on 1.25% gradient between the same points. This is a loss of distance of 2½%. The writer considers this a direct or straight line.

The map of the located line from Ottawa, Kan., to Council Grove, Kan., is shown on Plate 1 (p. 46). The country was not easy. The line does not look to be very direct, yet the percentage loss is small. The straight line scales 66.60 miles and the located line measured 70.37 miles. A loss of 5.35%. The writer considers this a reasonable loss for rather difficult country. Maximum gradient 1.25%, maximum curvature 5° average. Curvature per mile 23° 37′, average grading per mile 19,185 cubic yards. In locating this line the air line was kept constantly in view. This map and percentage of loss in distance show the wisdom of not turning angles for the purpose of *getting back to* the air line between controlling points.

The crossing of the Red River in Texas by the Fort Worth & Denver City R. R., Fig. 15, certainly represents the limit of disregard of direction. The primary drainage is at an angle of 45

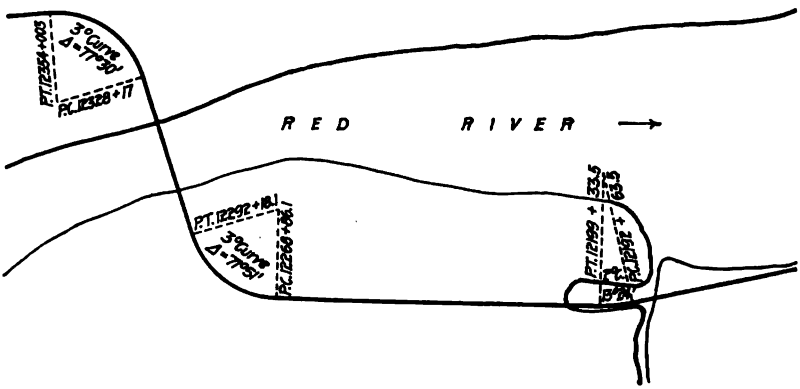

Fig. 15.

degs. with the direction of the road. The bridge is 14-ft. spans. These streams give trouble through washouts if overflow runs along the sandy embankments. This map shows an extreme in departure from direction. The angles, both beyond 70 degs., turned represents an extreme departure from direction unless loops or switchbacks be contemplated. Yet the tangent just back of the crossing should have led farther to the left and the angle of 77 degs. thus increased somewhat. The writer was informed by the Chief Engineer, T. E. Bissell, C. E., building the line that his not doing so was an error, and understands that this tangent was pivoted to the left so as to keep entirely up on the bluffs.

CHAPTER V.

GEOLOGY IN ITS RELATIONS TO TOPOGRAPHY.

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If there are laws governing the origin and development of topographic forms, nothing is clearer than that a knowledge of these laws must be of great importance to those who have to deal with such forms; and, indeed, there is a constant demand, among those who have not devoted much time to a study of the subject, for short and simple empirical rules for topography. There are such rules for topographic forms, but they hold good only in limited areas, and fail utterly whenever their general application is attempted. There is also a widespread disposition to appeal for explanation, especially of bold topographic forms, to the supernatural, to violent cataclysmic disturbances, subterranean upheavals, volcanic outbursts and "blow-outs," and to the Miltonian idea, in which: "The mountains huge appear emergent, and their broad, bare rocks upheave into the clouds." One serious-minded writer thinks the great gorge in the Cascade Mountains, through which the Columbia River flows, was made by God drawing his finger across that range.[1]

To arrive at any comprehension of topography, such ideas must be put aside at the outset; and the laws that mould topography to-day, the agencies which produce it, the materials worked upon, and how the work is done, must be studied before the results càn be understood.

Topography is the expression of geologic structure pretty much as the outlines of the human body are the expression of its anatomical structure. To be more precise, topography is the resultant of the operations of eroding agencies and the resistance of the rocks, the time of their exposure, the initial position of the surface, and the orographic changes suffered. These are all fundamentally matters of geology, and the following generalizations may be laid down without fear of successful contradiction: first, that no one can understand topography unless he comprehends the geologic reasons for it; and secondly, that unless one understands topography he cannot represent it correctly. To set a man at work on topography who knows nothing of geology

[1]Journal of an exploring tour beyond the Rocky Mountains, by Rev. Samuel Parker, Ithaca, N. Y., 1838, p. 215.

is very like having some one perform a surgical operation who knows nothing of anatomy.

"We see according to the light that is within us." One cannot picture a subject he has not studied. However skilled a draftsman or artist may be in the technique of his art, unless he understands the animal or plant he has to draw, he cannot make a correct picture of it. In topographic representation this is equally true, and it is the more important because a large part of every map must be sketched in, and this sketching cannot be done properly unless he who does it knows what ought to be there. Unless the topographer knows what to look for he doesn't find it, or he finds only a part of it. This statement is based on no small amount of experience of this fact. It has been the author's duty to employ many topographers, and all his experience of their work has but confirmed this opinion.

On the other hand, one should never allow himself to be inveigled by geologic hypotheses from the path of engineering rectitude. There is good reason for the view held by some that a topographer does not need to concern himself with the causes of topography; that he has to deal with facts only, and that his facts are merely matters of position to be determined by the use of instruments and mathematics.

Certainly there could be no more serious mistake than for a topographer to abandon his points of control. I should be the last to have him give up any data in his possession in favor of hypotheses. But I would lay stress upon the important fact that no one can gather all the information necessary to a perfect map. Limitations are laid upon every topographer—limitations as to time, means and data—and his map must be made within these limitations. He cannot stake off and run out his contours. Much of every map is sketched in between the points of control, and I simply maintain that the man who has a knowledge of the factors determining relief will know best how to distribute his points of control and will thus obtain, for a given amount of time, money and labor a map vastly superior to one made by the groping methods that must be used by the man who depends solely upon instrumentation.

The fact that there is now and then a topographer who is able to make excellent maps without having studied the reasons for topographic forms cannot be accepted as determining the best training for the common run of students. Such men are quite the exception.

It is of the utmost importance to the topographer that he should know what kind of topography to expect, and, to this end, the more he knows of the materials in which topography is cast, and of the agencies that shape it, the clearer will be his insight, the less waste of time and energy will there be, and the truer will be his representation of the relief.

The object of this paper is partly to point out the origin and controlling factors of some of the more important topographic forms, and partly to show the necessity of a knowledge of geology —especially of structural geology—to the topographer.

ROCKS THE MATERIAL OF TOPOGRAPHY.

Topography as here dealt with is the representation of the forms of the earth's surface. These forms are impressed upon, carved in, or otherwise made of the soils and rocks of the earth's crust; but these rocks vary among themselves to such an extent, in hardness, structure, texture and position, that when subjected to the same shaping agencies they yield very different results. It is necessary, therefore, at the outset, that the topographer should have at least a general knowledge of the different kinds of rocks, what they are, how they originate, the changes to which they are subject, and of the forms of the masses in which they occur.

For our present purposes the rocks may be classified according to the forms and origin of their beds as follows:

Water-bedded rocks or those laid down in water as mechanical, chemical or organic sediments.

Wind-bedded rocks, or those deposited on land in the form of blown sand or dust.

Organic deposits, or those made by living organisms, whether animal or plant.

Igneous rocks, or those cooled from a molten condition.

ORIGIN OF THE DIFFERENT KINDS OF ROCKS.

Brief descriptions of the methods of formation of these different classes of rocks will be given, in order that the forms of the deposits may be understood, and eventually the topographic relief to which they give rise.

The Origin of Water-Bedded Rocks.—Water-bedded or sedimentary rocks are those made of sediments, or fragmental, or skeletal materials, whether of mineral or organic origin, and laid down in water.

The sands, gravels, and clays washed by a stream into a lake or sea settle to the bottom and form beds of mechanical sediments. In time the sands form sandstones, the gravels make grits and conglomerates, and the clays make shales and slates. When the microscopic organisms that live in the sea perish, their skeletons sink to the bottom and form beds of organic origin. Waves beat upon shores strewn with molluscan shells or upon coral reefs, break off fragments and grind them to powder, and this material is swept out by the undertow and sinks to the bottom to form sedimentary beds of organic origin. All these sedimentary deposits, whether they are coarse, heavy cobblestones,

small pebbles, sands or clays, are deposited in approximately horizontal layers in the bottom of the lake, sea, or ocean.

It is important to note also that the marine sediments are either carried down from the land by streams or are taken from the immediate shores and carried out to sea by the undertow. It follows in either case that the heaviest sediments, the boulders and pebbles, sink to the bottom first and nearest the shore, while the finest silts, the clays, are carried farthest. The currents bearing the finer silts seaward are seldom checked suddenly, and the result is that the weight of the particles which can be carried in suspension decreases with the force of the current. For this reason, over any given area, the coarser sediments merge imperceptibly into the finer ones.

When, in the course of the earth's history, such beds are lifted from the sea bottom to form land, the peculiarities and local variations of these deposits must have some influence on the topography carved in them.

In the case of marine sedimentary beds, made up wholly or largely of the skeletal remains of microscopic organisms, the deposits are not so liable to local variations as are the mechanical silts. These marine organisms live in the water at or near the surface, and their remains sink to the bottom over large areas, while the uniformity in their sizes and weights offers but little opportunity for any selective action by currents.

Some water-laid beds are produced by chemical precipitation. In the case of salt lakes, where the water is being evaporated, when it reaches a certain density, the gypsum in solution is precipitated, and further evaporation causes the precipitation of the salt. The beds thus deposited settle over and conform to the bottom of the basin, and are therefore, in form, very like mechanically deposited sediments.

Wind-deposited rocks occur as widespread deposits of dust or as sand dunes. There is a tendency for wind-borne dust to accumulate in the eddies behind obstructions of any kind, whether natural or artificial. In deserts where clusters of bushes and tufts of grass form small scattered wind-breaks the dust heaps up about them in hummocks that vary in size according to the efficiency of the wind-breaks and their distances apart. If in time these plants die or are destroyed the region is left covered with thousands of small hummocks, sometimes known as "hog-wallows."

Along open seashores sand dunes form in lines at right angles to the direction of the prevailing winds. Obstructions, however, such as trees and clusters of bushes allow the sands to fall in the lee and to form long dunes parallel to the direction of the prevailing winds.

Organic deposits, other than those already mentioned, are coral reefs and peat beds. The coral reefs produce some of our

limestone beds, while lignite and coal have been formed from peat. The coral reef rocks are the skeletons secreted by coral polyps. The reef-building forms of these animals can live only in warm (68 deg. Fahr.), shallow (less than 150 ft.) sea water, and they are thus obliged to extend their beds horizontally, except where by slow subsidence of the sea bottom they are enabled to grow upward.

Peat grows only in moist places, and for the most part in flat, marshy ones, such as the Dismal Swamp of Virginia, the peat bogs of Canada, New England, Ireland, etc. In the course of geologic time the peat becomes lignite, and still later coal. The interstratification of coal beds with marine sediments can only be accounted for by supposing the peat beds to have sunk beneath the sea, and that subsequent elevation permitted the re-establishment of the peat swamps.

Igneous Rocks.—The rocks that have been in a molten condition include the masses that have been poured out through the crust and over it as great lava outflows, those that have filled and cooled in cracks in other rocks, and also the materials that have been blown out by volcanoes and have fallen to the earth as ashes and scoriae. Where these rocks have been spread over the surface as lava sheets, their early forms have been determined by the fluidity of the molten rock and by the surface over which they have spread. Sometimes they have been submerged after cooling, and sedimentary beds have been laid down on top of them. Where they have been intruded into crevices, their forms have been fixed by the crevices themselves. These are known as dikes. In the cases of fragmental materials blown from volcanic vents, the forms are limited to local accumulations lying in conical heaps. Sometimes these materials have fallen in water, and, settling to the bottom, have taken on the appearance of sedimentary beds, so far, at least, as their gross structure is concerned. Such beds are known as water-laid tuffs.

THE INTERNAL CHANGES AFFECTING ROCKS.

The materials of sedimentary rocks are at first soft and incoherent, but in the course of geologic time most of them become compact and hard, either from the pressure of other rocks heaped upon them, or on account of the deposition within them of cementing materials, or from a combination of the two, or on account of metamorphism or internal changes.

Angular rock fragments form breccias, pebbles and gravels; other coarse sediments form conglomerates, or pudding stones; sands form sandstones, and clays form shales or slates. The calcareous organic remains form chalks and limestones, while siliceous organisms make siliceous shales, diatomaceous earths, cherts, flints, novaculites, and jaspers. Peats form lignite and coal. Even the igneous rocks themselves are often greatly changed by being

reheated or by the action of hot water. These changes are all internal; some of them are the results of physical forces, such as pressure, while others are of a chemical nature.

STRUCTURAL CHANGES IN BEDS OF ROCKS.

Although the sedimentary rocks were originally laid down in approximately horizontal beds, yet, where they have been lifted from beneath the water, they have not always risen evenly. Their horizontality has been disturbed; they have been tilted this way and that, sometimes thrown into gigantic folds miles across, sometimes into wrinkles or close crumples, and sometimes they are broken, and the edges of the beds have slipped past each other. These last mentioned breaks and displacements are called faults.

Folds and faults are likely to occur in groups, that is, gentle folds occur together, and closely squeezed folds occur together, but the two kinds are not often found in the same region. Folds may be long or short. Short folds often overlap each other slightly at the ends. The axes of folds are generally approximately parallel in a given area.

Faults are also disposed to parallel systems in a given region. They may be close together or far apart; and the amount of displacement may be anywhere between a fraction of an inch and thousands of feet.

It is of the utmost importance to the topographer that he should understand these folds and faults, for they frequently have a great influence upon the topography. Regarding the size, character or relations of folds and faults, there is no general law that can be laid down in anticipation of what may be found in any new region. Their distribution is seldom to be anticipated, but must be determined by a study of the outcrops, or of the exposures of the rocks at the surface or in mines, tunnels, wells, railway cuts, etc. A knowledge of the methods of determining and locating these structural features is indispensable.

TOPOGRAPHIC RELIEF.

The topography of the globe may be classed as the major relief, including continental masses, great mountain chains and peaks, and minor relief or the details of topography. The forms and causes of the major relief will not be considered here; for our present purposes it is enough to remember that if the details of topography be properly represented the major relief will take care of itself.

If a lava stream emerges from beneath the earth's surface and spreads out over a wide area, it will, if a very fluid lava, form a flat surface by filling up the existing irregularities, much as if the region had been submerged by water and the water had frozen. If a volcano should burst forth upon a plain and

should eject large quantities of pumice, scoriae, cinders and the like, these materials would accumulate about the mouth of the vent and build up a volcanic cone. In both instances the topography would be formed by direct construction.

If a part of the ocean's bottom should be uncovered or brought up and left as dry land, it would be found that this new surface had certain irregularities; but rain and frost and streams would soon begin to attack it, to cut channels in it and to produce topographic forms altogether different from its original surface. The new shore line, at first comparatively smooth, would at once be attacked by the waves, and a steep-faced bluff would mark the new beach. All this cutting and shaping of the new topography would be the work of removing or of destructive agencies.

These two general classes or agencies--the constructive and destructive—produce most of our topographic forms. They will be considered in this order.

CONSTRUCTIVE AGENCIES AND THE FORMS THEY PRODUCE.

Subaqueous Forms.—Constructive topographic agencies, in the broad sense, should include subaqueous constructive forms; but while the forms of delta deposits and off-shore accumulations generally are constructive forms, they are of comparatively little topographic importance, because after emergence they are usually soon obliterated, as deltas and the like. There are well-known instances, however, of such forms, and for that reason they will be briefly described.

When a stream carrying silts enters a quiet body of water, the checking of the current causes some of the silts to fall to the bottom. In fresh waters some of the finest particles remain for a long time suspended in the water, but the salts in salt water cause these fine particles to flocculate or cling together in little bunches and thus hasten their sinking to the bottom. Wherever a muddy stream enters a lake or sea the silts it bears fall to the bottom about the stream's mouth and, in time, build up deltas such as are found about the mouths of the Nile, the Rhône and the Mississippi.

Deltas.—These deltas, through the operations of floods, build up so as to rise above the average water surface. They are flat on top, while their seaward faces may slope off more or less rapidly into deep water. In outline they tend to be fan shaped. Wherever there has been an elevation of a delta deposit above water, the form has been found like that here described. The Great Salt Lake in Utah not long ago covered an area of 19,750 square miles, and the streams flowing into it made deltas, which, by the drying up of the water, have been left uncovered. Wherever the waves of that lake beat upon its shores, accumulations of considerable size and extent were formed. These deposits are

now part of the surface relief of the region, and are locally of much importance.

Spits and Bars.—Bars are formed about the mouths of streams by conflicting currents. When a stream enters the ocean its current tends to sweep the sands it bears out into deep water; but when the tide comes in, the current is reversed and flows up the channel of the stream, and these sands are carried in the opposite direction. The sands tend to accumulate on some middle ground where the currents balance each other, and here they build up a bar which, by the help of storm waves and high tides, may rise above the water. Sometimes conditions may favor the accumulation of these silts on one side of a stream's mouth rather than the other, and they may stretch across it, forming a spit.

Waves do not always break squarely against the shore, but more frequently the surf runs along the beach according to the angle of the wind with the shore. In some parts of the world the winds blow so constantly from one direction that the sands are always carried one way. When there is an obstruction on such a beach an eddy is formed behind it, and here the waves leave the sands they sweep along, and, in time, a long split or neck is built, commonly hooked at the outer end.[1]

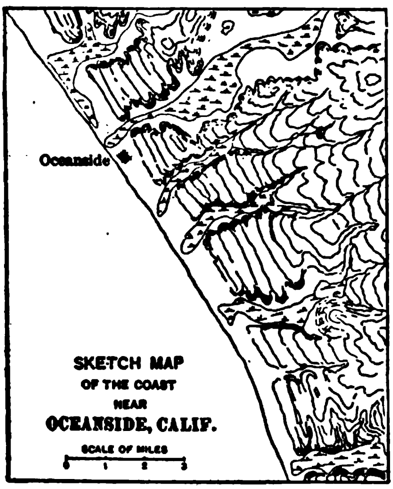

Fig. 16.—The coast near Oceanside, Cal., showing submerged valleys now occupied by marshes.

Emergent Forms.—Emergent forms of topography are those built up partly beneath the water, but gradually rising above it. Deltas built into dry land, lakes filled up with silts, turned into marshes, and later into dry land, are examples of this kind. Sometimes the fiords or submerged valleys along sea coasts have spits and bars formed across their mouths by the waves and the currents of the open sea, while in the quiet waters behind them the silts brought down by the streams are deposited until these bays are turned into marshes and then into dry land. In such cases there is an older and more precipitous topography diving beneath a new and nearly flat surface. The swamps near Oceanside, California (Fig. 16), and the long sandy beaches and bars along the coast of New Jersey, were made in this manner.

[1]For a comprehensive discussion of the topographic features of shores see "Lake Bonneville." By G. K. Gilbert, Monograph I., U. S. Geol. Survey.

Storm beaches and coral islands rising above the surface of the sea are also constructive emergent forms of topography. River terraces are produced partly by the constructive and partly by the destructive work of streams. Stream valleys are filled with silts and débris at times of floods, and when the streams shrink they cut their channels down through these materials, and in shifting from side to side leave terraces along their courses.

Subaerial Forms.—Subaerial forms produced by direct construction consist of volcanic ejectments and certain spring and geyser deposits.

Lavas.—The surface forms assumed by lava depend upon the fluidity of the lava and upon the character of the topography over which it is spread. In the case of very fluid lavas the angle of the slope built up is quite low, while those less fluid stand at higher angles, or even bunch up in steep-sided heaps at no great distance from their vents.

The basaltic lavas are of comparatively easy fusibility, while the trachytic lavas are of difficult fusibility. Consequently, basaltic lavas form flat sheets or lava cones of low slopes, while the trachytes, emerging in an almost pasty condition, are disposed to form steep-sided cones. Part of these differences, however, is due to the difference in the sizes of the outflows.

Lava Cones.—The profile of the great volcanic mountain, Mauna Loa, Hawaii, has so low an angle, from 4 degrees to 6 degrees, that it hardly impresses a person climbing it as being a volcanic mountain.

Cinder Cones.—Some volcanic cones are made up largely of loose ashes, scoriae or broken bits of rock that have been thrown into the air by subterranean explosions, and, falling near the vents, have piled up as cones of debris that stand at the normal angle of repose, which is from 33 to 40°. The lavas of Mauna Loa are basaltic; those of Mount Vesuvius are also basalts very little different from those of Mauna Loa, but Mount Vesuvius is made up largely of scoriae and ashes, while Mauna Loa is chiefly of fluid lava.

These general laws will give some idea of the methods by which such features are formed originally, and of the topography to be expected about active volcanoes. It must not be forgotten, however, that there are over the earth's surface a great many extinct volcanoes, and while these may still retain much of their primitive forms, they are more frequently than otherwise so modified by eroding agencies that their characteristic outlines have become partly or entirely obliterated.

One peculiarity of the erosion of cinder cones is worthy of note in this place: the loose materials on the slopes of such peaks allow the water falling upon them to sink beneath the surface at once. In this way these peaks avoid much surface erosion,

but the water issues as springs about the bases of the mountains, and their erosion cuts backward into the cones.

Spring Deposits.—These are formed by the precipitation from solution of the mineral matter brought to the surface by subterranean waters. They are of local importance only and are omitted from this discussion.

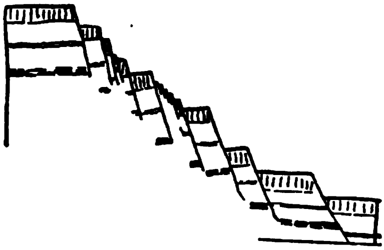

Fig. 17.—Section through normal faults, showing the repetition of the same beds in a step-like topography.

Faults and Folds.—In a sense those forces which produce folds and displacements of the rocks may be looked upon as constructive. There may be, for example, fault escarpments, or freshly made folds, producing very marked topography. Such cases, however, are not so common as one might suppose, for the reason that the original outlines of features made in this way are soon modified by erosion to such an extent that they are thoroughly obscured or even entirely obliterated.

In the case, too, of both faults and folds the displacements often take place so slowly that erosion keeps pace with the movements, and the structural features produced by them never appear as marked topographic forms. In some cases, however, faults have produced marked topography. In most faulting there is a crack or break in the rocks, and on one side of this break the edges of the fractured rocks are lifted above their former position, thus forming a step-like bluff. This escarpment may be from a few inches to several hundred feet high, and may be many miles in length. Such breaks are seldom straight, but have rough and more or less irregular edges, so that in detail a bluff produced by a fault is likely to be irregularly serrate or zig-zag in direction, although its general course may be approximately straight.

Fig. 18.—Section across normal faults, producing parallel ridges and valleys in a relatively flat region.

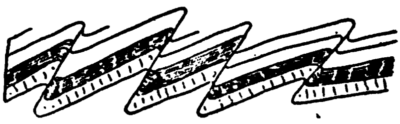

Fig. 19.—Reversed faults, produced by pressure. The faults all dip in the same direction.

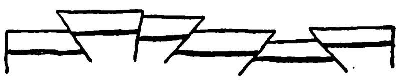

Fig. 20.—Reversed faults, produced by pressure, and dipping in different directions.

The surface forms that may be produced by faulting are almost as many as the forms of the fractures, depending upon the character and position of the rocks, the character of the force producing the faults, and the inclination of the fault face to the earth's surface.

Figs. 17, 18, 19 and 20 represent ideal vertical sections through the earth's crust. The upper surface in each case represents the surface of the ground. In Figs. 17 and 18 the faults have been produced by tension, while in Figs. 19 and 20 they have been produced by pressure. These faults may be close together

Fig. 21.—Photograph of N. F. Drake's relief map of California, showing the Northwest-southeast valleys, due to erosion along fault lines.

or far apart, single or double, or they may branch out in different directions. While faults are not confined to any particular area or rocks, they are much more abundant in some regions than in others, while in some they may be entirely wanting. In a given region faults often show a decided tendency to occur in parallel

sets, and these may cross each other at rather constant angles. In the Coast Ranges of California, for example, the faults are for the most part parallel to the coast line and the main axes of the mountains (see Fig. 21).

The original folds of surface rocks have, as a rule, been so long exposed that their primitive forms have been entirely destroyed. The long, narrow valleys of California, running parallel with the coast and with the Sierras, were produced originally by faults, but they have been greatly modified and widened by stream erosion. As in the case of faults, the folding of rocks has taken place so slowly that erosion has been able to remove obstructions as rapidly as they arose across the drainage. Even in cases of anticlinal ridges, there have almost invariably been thick overlying beds removed from them. The characters of folds will be discussed under the head of topography of "folded rocks."

DESTRUCTIVE AGENCIES AND HOW THEY OPERATE.

Eroding Agencies.—Most topography is cut in the rocks of the earth's crust. All rocks exposed over the earth, whatever their origin, are subject to the action of those natural agencies that cut out topographic forms. These agencies act with such extreme slowness that it is no easy matter to realize their importance, or even to believe that such vast results can be produced by such apparently trifling forces. If, however, one can realize something of the immense periods of time during which these agencies have been at work, there will be no difficulty in comprehending the results.

Any agency that causes rocks to disintegrate or decay, or that removes them, either before or after they decompose, must necessarily influence the form of rock surfaces; but it is also to be noted that an agency may be active at one place and not at another, at one time and not at another, or under some conditions and not under others.

The agencies that attack, remove, and modify the land surface are as follows:

Water, in the form of moisture in the atmosphere, rains, springs, streams, waves and glaciers.

Atmospheric agencies, by means of winds, changes of temperature and frost.

Moisture in the Atmosphere.—This affects the rocks by hastening the chemical decomposition of their constituent minerals.

Rains, Springs and Streams.—The direct mechanical effect of rain falling upon rock is of comparatively little importance; its chief work is done, not in falling, but as it flows away. A part of this water flows away over the surface, and a part sinks into the earth, passes through the soil and rocks, and, sooner or later, emerges as springs. Before it enters the ground it usually absorbs

more or less organic acid of one kind or another, and this acid greatly facilitates its chemical activity. In its passage through the rocks it dissolves more or less mineral matter out of them, and when it emerges as spring water it carries in solution considerable quantities of the mineral constituents of the rocks. No water has ever been found issuing from the earth that did not have more or less mineral matter in solution, while in some of these waters the quantity is enormous. In order to appreciate the amount of rock borne away from the land to the sea in this manner one need only determine the amount removed by a single spring or by a single stream.

In 1887-88 the author carried on a series of observations on the water of the Arkansas River, at Little Rock, where it was found that the dissolved mineral matter in one U. S. gallon of the water varied from 11 to 70 grains. The total quantity of mineral matter removed in solution in one year was 6,828,350 tons.

The materials carried down in solution in this stream are necessarily removed by water from the rocks over the hydrographic basin drained. Similar work is done by all streams, whether large or small, though the amount of material in solution in the water depends more or less upon the character of the rocks of the hydrographic basin. This is only the chemical work of water; its mechanical work will now be considered.

The simple fact that water flows off the land along the depressions is sometimes cited as evidence that these depressions have been made by the water. It is well said by those who object to this explanation of valleys that the water could not possibly flow elsewhere. This fact alone can not, therefore, be regarded as evidence that valleys are made by streams.

The process of channel cutting will be better understood if a perfectly flat surface is assumed as exposed for the first time to subaerial conditions: rain, snow, frost, streams, changes of temperature, etc. If this flat surface has a gentle slope, the water falling thereon will flow down that slope, and the streams will unite and become larger as they approach its base. In time the running waters will wash out channels for themselves, and, as time goes on, these channels will be worn deeper and deeper. In such a case the channels are evidently cut by the streams.

If, instead of a flat surface, there is, to begin with, an irregular one having a uniform, gentle slope, the water will seek the depressions from the outset, and the deepening of channels will proceed from these predetermined drainage lines. In both cases the details of the final relief of the region will be the result of the wearing and carrying action of the water. Velocity is what enables water to carry materials heavier than itself. It follows, therefore, that any increase in the slope of a region must increase the velocity of its streams, while the velocity of the streams increases their carrying power. This relation of force to velocity is

expressed by the formula: $F \propto V^2$, in which F is the force of the current and V is its velocity; but the power of the water to move stones varies as the sixth power of its velocity ($F \propto V^6$;); that is, by doubling the velocity of a stream, its power to carry is increased sixty-four times.[1] Hence, any increase of the current of a stream enormously increases its power to sweep along the materials in its channel. It follows that the amount of materials carried along by a stream must vary greatly if the stream itself is subject to fluctuations of volume.

Some streams are always muddy, others only occasionally; but all muddy streams are so because they carry large quantities of mechanically suspended matter. The amount of material carried by such a stream as the Mississippi or the Amazon is almost beyond belief. The observations made by the author upon the Arkansas River, at Little Rock, show that that stream carries, in addition to the dissolved matter already mentioned, an enormous amount of fine sand and clay. At times this amounted to more than 700 grains to the gallon. The total amount of mechanically transported sediment carried past Little Rock in the year was 21,471,578 tons. The total amount carried down both in solution and in suspension, in the year was 28,299,929 tons, or equivalent to a cube 749.2 ft. on each side.

Similar determinations of the silts of the Mississippi River show that it carries out of its hydrographic basin every year a mass of mineral matter equal to a cube 1,954 + ft. on a side, without including the dissolved matter. This material can come from the basins of the streams only, and these determinations afford the means of ascertaining the rate at which the land surface is being removed. Over the entire Mississippi basin erosion goes on at the rate of a foot in 5,000 years.; over the Arkansas basin at the rate of a foot in about 9,000 years; over the basin of the Danube at the rate of a foot in 6,846 years; over the basin of the Rhône at the rate of a foot in 1,528 years; over the basin of the Po at the rate of a foot in 729 years, and over the Ganges basin it is at the rate of a foot in 823 years. The importance and bearing of this matter upon topographic relief will be seen presently.

Waves.—Waves do their chief work on the larger bodies of water—oceans, seas and large lakes. Although they are confined in their operations to narrow vertical limits, yet their force is irresistible, their work sharp and well defined, and the length of the lines along which they operate is coextensive with the shores of every ocean, sea and lake on the globe. Their work consists in undercutting the shores, rolling the talus back and forth, and

[1]A Treatise on Hydraulics. By M. Merriman, New York, 1891, pp. 251-252.

"The Suspension of Solids in Flowing Water." By E. H. Hooker, Trans. Am. Soc. C. E., 1896, Vol. XXXVI., pp. 239-340.

thus grinding up the coarser materials. These materials are either thrown on shore as shingle and sand or are swept out into deeper water by the undertow.

The effect of waves is important only on or near the beach, for they do but little work 20 ft. below tide or 50 ft. above high tide, except by undermining. When it is recalled that almost every part of the earth's surface has several times passed through a beach condition, the important part the waves have played in the earth's history may be suggested.

Glaciers.—In those parts of the earth in which precipitation takes place in the form of snow, the drainage is in the form of ice streams or glaciers. These glaciers carry down upon their surfaces, or within the ice, whatever rock fragments or soils may fall upon them, or that the ice can scrape from its rocky bed; and when the slowly moving ice reaches the point where it melts, this load of débris is dropped, or is swept along by the stream that flows from the melting glacier. The accumulations at the ends of glaciers are known as moraines. If, in time, the glaciers become much shorter, these moraines are left strewn over the ground formerly covered by the ice.

Atmospheric Agencies.

Winds.—In their direct action winds modify the earth's surface by moving sand dunes, by carrying the ashes of volcanos and dust in arid regions, and by forming natural sand blasts that cut and polish the rocks.

By their indirect action they are of even more importance, for they affect vegetation on the land, distribute moisture over the earth, help determine the force and direction of ocean currents, and, by raising waves upon water surfaces, enable the waters to undercut their banks and encroach upon the land in some places and to fill up and build beaches, spits and bars in others.

Changes of Temperature.—Changes of temperature tend to break up rocks by causing them to expand and contract alternately. The minerals of which the rocks are made do not all expand and contract alike in these changes of temperature, and this tends to pull the rock to pieces and allow acidulated waters to penetrate the crevices and finish the work of destruction.

Frost.—The expansion of water freezing in crevices of the rock hastens its disintegration. By the alternate freezing and thawing the rocks are rapidly broken to pieces and exposed to other decomposing agencies.

The Forms Produced by Destructive Agencies.

Most gorges, canyons, narrow valleys and stream channels are cut in the rocks by streams and other disintegrating and eroding agencies, while topographic prominences are simply the parts

left behind in relief. Hills and ridges are therefore high, not because they have been thrust upward, but because the country around them has been worn down more rapidly than they, and it is fair to assume that hills and valleys started very nearly at the same elevation. Although topography is thus chiefly the resultant of rock resistance and rock removal, the resisting powers of rocks vary so much, and the removing agencies work so differently under different conditions, that the problem, in its details, is a complex one.

Other things being equal, topography is dependent upon:

I. The character and alternation of the rocks.

II. The geologic structure, or the position of the beds, dikes and veins.

III. The joints in the rocks.

IV. The slope of the land surface.

V. The climatic conditions.

VI. Interruptions during development.

VII. The initial, primitive conditions or starting point of the drainage.

VIII. The length of time the region is exposed to eroding agencies.

IX. The nature and working methods of the eroding agency.

There may be any combination of these influences shaping the topography. However complex the combination may be, these agencies, when acting alone, produce comparatively simple results.

I. The Character and Alternation of the Rocks.—It has been stated that erosion goes on over the hydrographic basin of the Mississippi River at the rate of a foot in 5,000 years. It is hardly necessary to say that this erosion is not even, that this foot is not removed over the whole basin alike, but that it is simply an average for the entire area. At some points erosion is almost nil, while at others it is more than 1 ft. in that length of time. If in starting there were a perfectly flat, smooth surface having a gentle slope, the first rains might flow off as if from a sheet of glass; but this water would soon begin to wear here and there, and this wearing would always be more marked in the regions of soft rocks, and in a short time there would be developed, over this once smooth surface, a system of drainage that would come more and more under the influence of the rocks; that is, the channels would be cut deeper and deeper in the soft beds, while the harder ones would be left as prominences. This is shown in Figs. 22 and 22a, which are sections across alternate upright beds of hard and soft rocks.

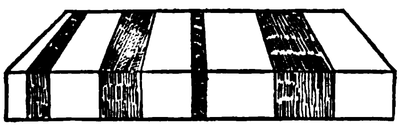

Fig. 22.—A smooth block of hard and soft rocks, the beds standing on end. The soft beds are shaded.

Under such circumstances in topographic development the alternation of hard and soft beds must determine the location of valleys and ridges, and any rearrangement of these beds would produce a corresponding rearrangement of the valleys and ridges. In the case of igneous rocks, often the molten material issues through crevices in the older crust, and, as these crevices vary greatly in form, the dikes that fill them vary as much. These dike rocks may be either softer or harder than the beds they penetrate. When they decompose more rapidly than the surrounding rocks, they form depressions; when they are more resisting, they stand out as ridges or walls upon the surface.

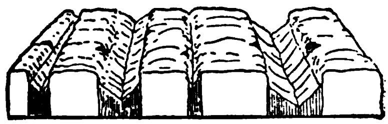

Fig. 22a.—A block of hard and soft rocks, the same as Fig. 22, after being subjected to a period of erosion. The streams cut valleys in the soft beds and leave the hard ones standing out as hills.

When they are of equal resisting power with the adjacent rocks, both wear away together without differentiating the topography; but whether these dikes make depressions or ridges, no definite law can be laid down for their direction. They sometimes follow parallel lines; sometimes they radiate from centers, and sometimes they seem to bear no apparent fixed relations to each other.

When the rocks are massive and homogeneous throughout, as in the case of granites and some gneisses, there are no marked lines of weakness to encourage selective action of erosion. These rocks, whether in large or small masses, frequently exfoliate or peel off, like the coats of an onion, and produce rounded or ball-like boulders of decomposition, or, on a large scale, they form dome-like hills and mountains.

These forms are characteristic of massive rocks only. They are well illustrated by Stone Mountain, in Georgia,[1] and by the exfoliated boulders and peaks of Brazil.[2]

The destructive work done by water in dissolving the mineral constituents of rocks has been spoken of. It follows that the more soluble rocks are affected by chemical activity more rapidly than those less soluble. Limestone is one of the most soluble rocks, and for this reason it is everywhere attacked by water and removed in solution. Water does not confine its action to surface exposures, but penetrates the crevices in the rocks and attacks them often far beneath the surface. The removal of large quantities of rock from deep down below the surface gives rise to caves, sometimes of vast extent. Often the caves are not far below the surface, their roofs give way, the soil slides down and,

[1]A Treatise on Rocks, Rock-Weathering and Soils. By Geo. P. Merrill, N. Y., 1897. Frontispiece. North Carolina and Its Resources, p. 115.

[2]Decomposition of Rocks in Brazil. Bul. Geol. Soc. Am. VIII, pp. 272-277.

concealing the old cavities, forms what are known as sink-holes. These sink-holes are filled with water, and ponds mark their positions. Caves and sink-holes are confined for the most part to the regions of limestone rocks, and the drainage of such a region is frequently almost all underground.

II. The Geologic Structure, or the Position of the Beds, Dikes and Veins.—Rocks do not always stand on end, as in the case supposed above, but lie in every conceivable position, from horizontal to vertical, or are even overthrown. They are bent into broad, gentle folds, or squeezed into close wrinkles, or are broken by faults and tipped about in all kinds of positions. It is not necessary to consider what caused these folds; it is enough to know that they exist, and that the axes of the folds are not necessarily parallel.

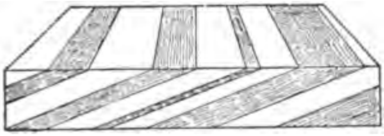

Fig. 23.—A smooth block of hard and soft beds of rock, the beds dipping to the left. The softer beds are shaded.

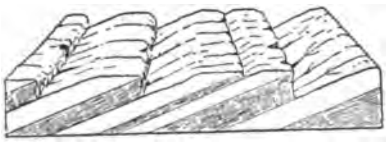

Fig. 24.—The same as Fig. 23 after having been subjected to a period of erosion. The streams follow down the dip of the soft beds.

As a rule, streams and eroding agencies avoid hard rocks and seek out the soft ones. It follows, therefore, that this selective power of water in attacking the rocks must produce different topographic effects according to the positions in which the rocks stand. Indeed, erosion is entirely guided by the rocks in many cases, while in all cases they direct it to a greater or less extent.

Beginning with the flat, smooth surface shown in Fig. 23, as in the previous instance, beds of the same kinds and in the same relations to each other will yield a topography suggested by Fig. 24, the streams following the soft (shaded) beds down the dip. Fig. 25 represents alternate hard and soft (shaded) beds dipping in various directions.

In a region of gently dipping rocks, the streams, following the strike of the beds, move down the slopes at right angles to their courses. Folded beds yield a great variety of forms according to the character of the rocks, the nature of the folds and the age of the topography. But they all follow the same general law; erosion removes the soft beds, the harder ones are undermined in some cases, in others they stand out as rock walls.

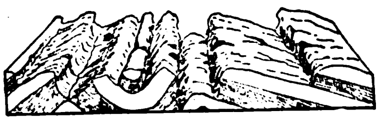

Fig. 25.—Ideal section across a region of folded rocks showing the streams, following the soft rocks in opposite directions.

The accompanying sketch map (Fig. 26) of the country near Conway, Ark., illustrates well the influence of hard and soft beds

in a region of folded rocks. Here the almost unbroken ridges of sandstone can be traced for many miles, swinging around the anticlinal noses and back again around the synclinal spoons like

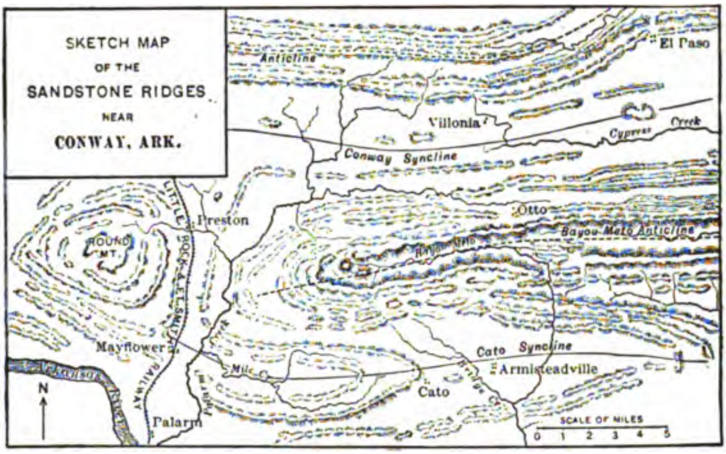

Fig. 26.—Example of parallel ridges and valleys due to erosion of folded alternate hard and soft beds.

the hard and soft grain of a pine board. Round Mountain in this area is made up of such layers worn away till their remnant looks like a nest of gigantic dishes.

When the alternate hard and soft beds are horizontal, as in

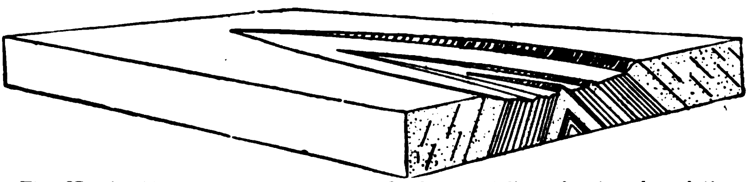

Fig. 27.—An ideal section across the end of an anticline, showing the relation of the fold to the topography.

Fig. 29, the topography is different from any of these forms. In this case, the soft layers may be removed by the action of frost, or weathering in various ways, or by water flowing down the face

Fig. 28.—Terrace-like topography due to erosion of horizontal strata (Simonds).

of the bluff. In either case the removal of the soft layers undermines the hard beds and these eventually break down in blocks.

As this process goes on, the profile of the hill does not necessarily change much beyond a certain point until late in the life of the hill, when the hard layers will be removed one by one. Where the beds are thus horizontal they tend to make a terrace or step-like topography (Fig. 28).

Such "bench-and-bluff" topography, as it is sometimes called, is quite common in many parts of the arid regions of the United States. If, in a region of horizontal rocks, the valleys are short and narrow, the slopes will be more or less even, but where the streams, either through the age of the drainage or the width of the valleys, have meandering courses, there will be a marked variation in the slopes of the opposite sides of the streams. Such topography is represented in Fig. 30, which is that of a meandering stream, and is common in certain portions of the Ozark Mountains of Arkansas and Missouri.

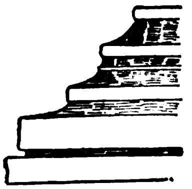

Fig. 29.—Ideal section across the ends of horizontal strata of alternate hard and soft beds.

If, instead of alternating hard and soft beds, we have horizontal rocks, nearly uniform in character, they frequently form tall, slender columns; "pulpit rocks," or "chimney rocks," as they are often called. The flatness of a plain is sometimes due to the exposure over its floor of a resisting horizontal bed.

The foregoing discussion of the development of topography in regions of sedimentary rocks has proceeded on the theory that the beds are uniform in thickness and constant in character. As a matter of fact, there is no such uniformity in the rocks of Nature, and the reason is apparent when the conditions under which the beds have been formed are considered. This variation in thickness and character, this changing of a sandstone into a shale a mile away, and to limestone further on, yields a corresponding difference in the topography developed from these rocks. Ridges prominent at one place die down and are replaced by valleys and are overlapped by others which here are insignificant and further on are bold and mountainous.

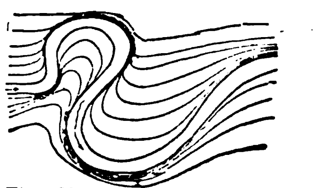

Fig. 30.—A meandering upland stream, cutting its way down through horizontal homogeneous rocks, and getting more crooked.

It should be noted in regard to the structural forms spoken of here or elsewhere in this paper, that they are not always, or even commonly, seen exposed in Nature. They are, for the most part, concealed by soils, undergrowth or forests, and these structural features can only be made out by the study of isolated exposures over wide areas.

Owing to the peculiar method of attack on sea shores—along

a horizontal line—structural features yield characteristic forms where cut by waves. Where hard and soft rocks stand on end and their strike is at right angles to the general coast line, the details of the shore will be very irregular owing to the yielding of the soft beds and the resistance of the hard ones, as represented in Fig. 31.

If the beds are tipped up and dip toward the water, the sloping beds will act as an effective breakwater, against which the waves can have but little power. If the beds are horizontal or dip away from the water, the waves will undermine them by attacking the soft beds at their lower exposures.

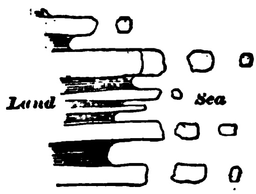

Fig. 31.—Plan of sea coast having alternate hard and soft (shaded) beds, standing on end.

Dikes and veins in places resist erosion and are left standing out like more or less broken walls over the landscape. In certain parts of California, where the so-called Mariposa slates come to the surface, denudation leaves them standing on end and giving character to the landscape over wide areas. For this reason they are popularly known as "tombstone rocks."

Under other heads are discussed various influences that affect the details of topographic relief. Each of these influences is important in its own place, but there is no one of them that so uniformly and so persistently moulds topographic details as does geologic structure. For this reason especial attention should be given to the structure when it becomes necessary to understand or represent the topography.

The author has been asked to explain the rules for topography suggested by M. L. Lynch.[1] The first rule is: that with "a stream flowing east or west * * * the south slope of the valley is generally steeper."

This rule holds good in a region in which the rocks have a gentle south dip, but not elsewhere. If the rocks dip north at the same angle, the steep slope will be on the north sides of the streams.

The other rule is that "in a stream flowing north and south, the east slope of the valley is invariably steeper." * * *

This rule holds in a region where the rocks have a gentle east dip, and not elsewhere. If the rocks dip west and the streams flow north or south, the steep slopes will be on the west sides of the streams; in other words, both rules would be reversed if the dip of the rocks were reversed.

Such rules may be most useful in the regions in which they originate, but they are of no value, and may, indeed, be very misleading in a region of different geologic structure.

[1]Trans. Am. Soc. C. Eng., 1894, XXXI, 82.

III. Rock-Joints.—The joints or systems of cracks in the rocks often guide streams in their development, and give character to the details of the topography. This will not be discussed at length. Good illustrations of this influence may be found in Dutton's "Geology of the High Plateaus of Utah," plates VII (op. p. 253) and X (op. p. 280), in Daubrée's "Géologie Experimentale," pp. 324-373, and in H. W. Turner's paper on the origin of Yosemite Valley, published by the California Academy of Sciences.

IV. The Slope of the Land Surface.—From what has been said of the transporting power of running water, it follows that streams with steep gradients carry away whatever materials lie in or fall into their channels much more rapidly than those with lower gradients, in accordance with the formula $F \propto V^6$. Besides carrying away sand, gravels and boulders, such streams corrode,or, by means of the impact of the moving materials, wear and cut their beds; and as increase of velocity is a factor of so much importance in this connection, it follows that the slope which produces the velocity is the prime factor.

If a slope were perfectly even, if the rocks were of the same character from top to bottom, and if the stream were of the same size throughout, the cutting along its channel would be uniform from one end to the other. But the gradient of every stream varies more or less from one part to another. The rocks also vary, and there is, therefore, a tendency for it to have alternate cataracts and slack currents. The long slopes of mountain chains are frequently not eroded most rapidly at their steepest parts, but this is due to the fact that these steep grades are near the crest where the streams are small. In Fig. 32, if the full line represents the slope of an original surface, the amount of erosion down the slope would be indicated by the distance between the full and dotted lines.

Fig. 32.—The heavy line representing the profile of a hill, the amount of erosion along its slope would be represented by the distance between the two lines.

Whatever deviations from this rule are found are due to other conditions, such as variation in the rocks, structure, changes or time. In general the elevation of a country, by increasing the slope, affects the topography by increasing the velocity of its streams, and hence their rate of erosion, thus allowing the formation of deep gorges.

Climatic Conditions.—Inasmuch as topographic features are carved chiefly by running water, it follows that there is but little carving done in regions without water. Perfectly arid countries therefore are subject to but little change from this cause.

The wind-blown sands, and the breaking up of surface rocks by changes of temperature, are the most potent agents of change in such regions. In cases, however, in which streams flow through these regions, they produce very marked topographic

effects, owing to the fact that they erode their beds and clear their channels, while the walls forming their banks are but little affected by the climate.

There is no more remarkable illustration of this peculiarity of the work of streams in an arid region than that of the Grand Canyon of the Colorado, where the Colorado River, rising in a region of heavy precipitation, in the Rocky Mountains and Wasatch Mountains, flows southwestward across the arid regions of Southern Utah, Northern Arizona and Southern California.

An excellent illustration of the influence of climatic conditions on topography is found in the "Knobstone" of Indiana. Professor John F. Newsom, of the University of Indiana, who has been working upon the geology of this formation for several years, has informed the author that this rock is highly susceptible to weathering influences; so much so that the south-facing slopes are, as a rule, gentle, while those facing the north are abrupt. An article by J. T. Campbell[1] offers a different explanation for the topography of the "Knobstone," but the author's own observations on this rock agree entirely with those of Professor Newsom.

V. Interruptions During Development. Faults.—The crust of the earth is nowhere perfectly stationary, but is constantly, though for the most part imperceptibly, rising or sinking. Now, if elevation takes place across the channel of a stream, the stream will cut through the obstruction if it does not rise too rapidly. In most cases such changes during the life history of a stream do not involve great elevations, but in some instances there is the spectacle of a river cutting a deep gorge through a mountain.

If an elevation across a valley takes place more rapidly than the stream can cut, a lake will be formed. Such instances are known, but they are not common. In a mountainous region the streams are rapid; therefore they cut faster than they otherwise could, and obstructions, in order to make lakes, must rise too quickly to be cut down at an equal rate. A lake made in this way is soon filled up with silt. Immediately thereafter the outlet cuts the dam down slowly, and the stream sinks through the silts of the former lake, leaving terraces on the sides of the valley.

Calaveras Valley in Santa Clara County, California, was formed in the manner here indicated. The accompanying sketch map, Fig. 33, shows the flat floor of this valley with steep mountains on all sides. The obstruction was at the lower or northern end of the valley, and is now being removed by the stream. In such instances the downthrow must always be on the up-stream side of the fault.

Glaciation.—The development of a given kind of topography may be interrupted by glaciers pushing down over the region,

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[1]American Naturalist, Vol. XVIII, p. 367.

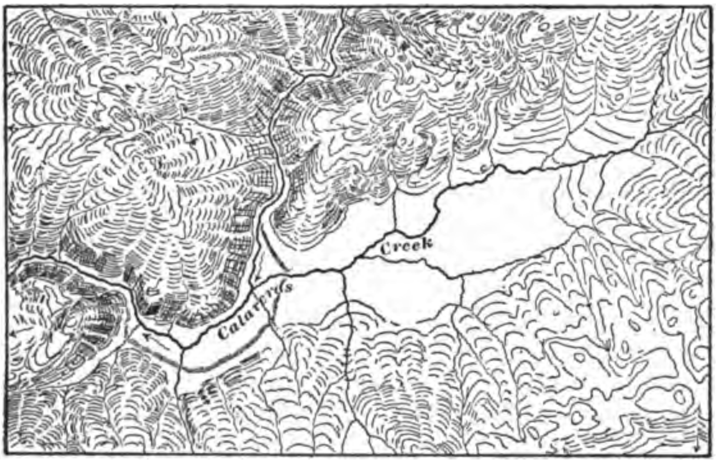
burying the former topography, and, after retreating, leaving a new relief and a new drainage determined by the accidents of glacial deposits. Such is the origin of the topography over much of the northern United States and Canada. The kettle moraines and glacial lakes of Minnesota and Wisconsin are a part of this glacial topography.

Igneous Eruptions.—Interruptions may be produced by outflows of lava damming streams and burying the topography of one epoch and giving rise to new drainage systems.

Sand Dunes.—Drainage is sometimes greatly modified or altogether changed by sand dunes damming up the streams and forming lakes.

Landslides.—In mountainous or hilly regions landslides sometimes cause temporary or even permanent dams.

Depressions.—Depressions that carry coast lines beneath the sea interrupt the development of the coast line topography and



SKETCH MAP OF CALAVERAS VALLEY, CALIF.

Fig. 33.—A fault rising across the lower end of the valley made a lake above the fault. This silted up, but the stream is now cutting its way down through the obstruction.

inaugurate a new one. One of the striking results of such depressions is the formation of fjords or narrow estuaries by the submergence of narrow valleys. Such are the firths of Scotland and the fjords of Norway.

VII. The Initial, Primitive Conditions or Starting Point of Drainage.—It often happens that folded and faulted rocks of various characters have been sheared or smoothed off by erosion, and that the area has then been submerged, and sedimentary beds have

been laid down unconformably on the older rocks; or lava sheets have been spread over these eroded beds without their being submerged. Whatever the drainage and topography may have been before the lava was spread over the area, or before the superposition of the new sediments, the new drainage will be more or less different from the old on account of the form of the new surface. The streams, starting under the guidance of the new topography, begin to cut their channels through the new rock, and sooner or later reach the old buried rocks. By the time the buried topography is reached, the stream is so closely confined to its channel that it is obliged to cut through the underlying rocks and to cling to its new channel regardless of the old topography. Such a system of streams is called a superimposed drainage, on account of its being let down from overlying beds regardless of the rocks in which it now runs. It should be noted, however, that when a buried topography is uncovered in this way, although the older rocks are unable to bring the drainage under immediate con-

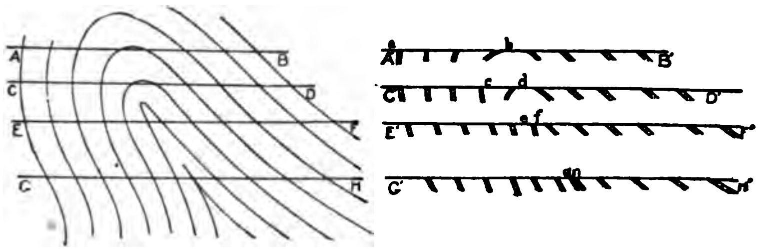


Fig. 34.—Diagram illustrating the structures exposed by eroding an overturned anticline to different depths.

trol, there is a constant tendency in that direction. Streams can in this way cut hills and ridges in two, but the rocks that form such ridges are simply notched like a board; lateral streams soon bring them into relief again, and the continuity of the beds can be traced across the principal streams. Erosion seeks out the soft beds again and avoids the hard ones—it goes in the direction of least resistance. The result is that the smaller streams are soon brought again under the control of the structure. Aside from the principal drainage lines, the chief topographic features, even in the case of a superimposed drainage, are controlled by the geologic structure.

VIII. The Length of Time the Region is Exposed to Eroding Agencies.—It has already been shown that when destructive agencies get access to a piece of the earth's land surface they begin immediately to attack it, to cut it down and wash it into the ocean. The general tendency of this operation is gradually to reduce the land surface to a low level. Before this level is reached, however,

the topography passes through a series of changes, and these changes vary according to the characters of the rocks, geologic structure, climatic conditions, accidents during the period, slope of the country, etc.; or, to put it differently, starting with a given piece of structure, the topography will not always remain the same, even in form, but will vary more or less with its age or with the length of time it is exposed to eroding influences. It is generally agreed that sharp rugged outlines, high and steep relief, waterfalls and rapid streams are characteristic of new topography, and that low relief, rounded outlines, and sluggish streams indicate an old topography. Within certain limits these are characteristic features of old and new topography, but there are many important exceptions.

IX. The Nature and Working Methods of Eroding Agencies.—With important exceptions erosion is done only by water and by ice in motion. The cutting of gullies, canyons and valleys, by streams, has already been explained. The removal of the walls above the stream-bed is greatly hastened by the changes of temperature and especially by the action of frost, which loosens and disintegrates the rocks and causes them to slide down and form talus slopes. When precipitation is only in the form of snow, the drainage of the region is effected by glaciers. These streams of ice follow the low ground like streams of water, and carry upon their surfaces, or within their bodies, or push over their rock floors, the soil and rock fragments that come within their reach. The stones, held fast by and pushed along in the ice, grind and wear away the hard rocks in place, rounding off the projections on the up-stream side. In cases of continental glaciers, such as those which now cover the antarctic regions and most of Greenland, it is reasonable to suppose that the up-stream sides of the hills that lie buried beneath these ice sheets are worn more than the down-stream sides. Geologists have found that a large part of the North American continent, nearly all the islands of Great Britain, all of Scandinavia, and large portions of Northern Europe, were once buried beneath a similar sheet of ice. The ice moved, not from the north toward the south, as was formerly supposed, but from certain centers outward. It everywhere affected the topography, in many cases leaving the hills more or less rounded on the uphill side, and everywhere strewing the débris over the country, and frequently piling it up in heaps and lines or moraines. The topography produced by ice is characteristic, and there is usually a strong contrast between glaciated and non-glaciated areas, even when the rocks in each are of the same kinds.

After this brief statement of the processes by which topographic forms originate and change, it is hoped that the original proposition may be accepted, at least to this extent: that there is not, and can not be, a fixed rule for all topographic forms, and

that in order to understand topography one must understand the geologic reasons for topography.

It should not be forgotten that the scale of one's map has much to do with the matter here treated. For example, mention has been made of the influence of faults upon topography, and the case of California cited in evidence. But the fault ridges and valleys of California are so large that there is no danger of their being overlooked on any map, unless it be upon a very small scale.

I can not close this brief discussion better than by quoting the words of the eminent topographer who first learned and ably pointed out the relations of geology and topography:

"That none but a geologist can make a map is evidently true from the fact that we only see what we look for, and the geologist alone looks for surface indications of internal structure; he knows, therefore, the importance and significance of what to any other man is nothing, or at least a curiosity."[1]

[1]Manual of Coal and Its Topography. By J. P. Lesley. Philadelphia, 1856, p. 192.

CHAPTER VI.

The Locomotive.

Railroad location is the avoidance of resistance to traffic, so far as topography permits. The resistances that can not be avoided may often be arranged in some desired sequence or be combined with a view to economy. The resistances to traffic which the topography offers, and the locating engineer does not avoid, must be overcome by the locomotive.

Intelligent railroad location demands an outline knowledge of the locomotive. The study of the locomotive lies entirely within the province of the mechanical engineer, just as the study of geology lies entirely within the province of the geologist. But as geology underlies topography, so do the principles governing locomotive power underlie the location of a railroad. Therefore it becomes necessary for the civil engineer engaged in railroad location to learn from the mechanical engineer a few of the fundamental principles of the locomotive. This should comprise some idea of the forces rather than of the design. It is necessary to know what an engine of the different classes used on a road will haul before designing a road for their use. Having this knowledge a railroad extension can be designed to use with economy some of the various classes of engines now on the road. It is true that an increase in the rate of grade may be met by doubling or otherwise increasing the number of engines. But the preferable plan is to increase the weight of the engine and so to design the line of road that one engine of a certain class may pull the train economically at desired speed over one division, and that on the adjacent division, with a steeper gradient, a class of engines existent on the road can haul that same train with the same economy and speed. This is the usual adjustment of gradient and curvature to motive power. Even when building a new road of considerable length the grades should be judiciously arranged so that the mechanical engineer can readily design or specify for purchase in the market, suitable engines for the different divisions. In the opinion of the writer, the civil engineer, when departing from one rate of ruling grade, does not change the rate of grade as much as he ought for economy. If, for example, a Mogul engine will just handle a train, and the topography compels an increase in the rate of ruling grade, why not change that rate so that a Consolidation engine can just haul the same train? If the lighter engine can not haul the load then the heavier engine must be used. Then give that heavier engine its working

load with the same train if it is used at all. If a rate of grade of 0.8% taxes one class of engines economically with a certain weight of train, and if a rate of grade of 1% taxes economically the next class of engines on the road, with the same weight of train, should you use 0.9%, or when 0.8% is abandoned use 1% at once? If this is not done new engines must be provided to operate the line economically. Location and motive power have been divorced unwisely. The civil engineer and the mechanical engineer must work together, or the interest of capital will suffer.

TYPES.

The locomotive is a wonderful machine. Its history is short. Its development is marvelous. Its usefulness to-day can not be measured. It has revolutionized civilization.

The American locomotive is divided into several types. Each type has a certain wheel arrangement, and by that means may be known.

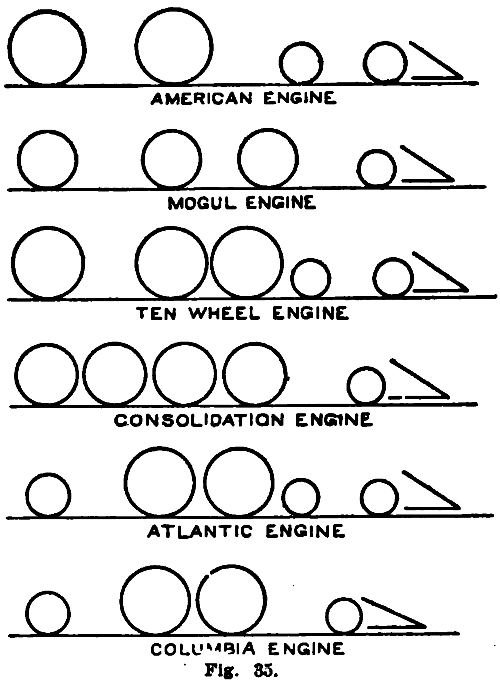


Fig. 35.

The "American" engine has two driving wheels on a side and a double, i. e., two-axle, truck in front. It is called the American engine probably because it was the first type used and made in America. The European locomotive has no truck or pilot in front.

The "Mogul" engine has three driving wheels on a side and a single, i. e., one-axle, truck in front. It is an early modification of the American engine, made necessary by heavier trains. The name would indicate that it was powerful as compared with others of its time. It is usually a freight engine.

The "Ten-Wheel" engine has three driving wheels on a side and a double truck in front. It was an advance upon the Mogul, and designed to take the curves of a crooked line better at high speed. It is usually a fast freight engine, but is often used on heavy passenger trains or on any passenger trains where heavy grades must be climbed.

The "Consolidation" engine has four driving wheels on a side and a single truck in front, It has, therefore, ten wheels, like the preceding type, but has one pair more of driving wheels and one pair less of wheels in its truck. This engine was designed by Mr. Alexander Mitchell, of Wilkes-Barre, Penna., a former Master Mechanic and Division Superintendent of the Lehigh Valley Railroad. It was intended to pull coal trains over Wilkes-Barre Mountain, on a 90-foot grade to the mile. The engine was built by the manufacturers under protest, and with the stipulation that the name of the makers should not appear on it. It was called a "consolidation engine" because it resembled two American engines consolidated together, since it had the driving wheels of two American engines. The first one built had the name "Consolidation" on its cab, and a picture of that engine was seen by the writer while employed on that road. This engine marked a long step in advance toward heavier engines. It is usually a freight engine.

The above comprise the usual types of engines. There are other, but less common types. The "Mastodon" engine is a Consolidation engine, with a double truck, instead of a single truck, A "Decapod" engine has five driving wheels on a side—hence its name. The "Columbia" engine has two driving wheels on a side, a single truck in front and a single truck, known as a "trailing axle," behind. This last feature is to allow greater length of boiler and grate and therefore a longer engine. The "Atlantic" engine has two driving wheels on each side, a double truck in front and a trailing axle. These last two engine types have sometimes other names in different parts of the country, and are high-speed passenger engines.

From the standpoint of railroad location, the forces of the locomotive, in the order of their importance, are as follows: (1) Traction; (2) boiler power; (3) transmission power. Traction is a function of that part of the weight of a locomotive which rests upon the drivers. It is computed by multiplying the total weight on the driving wheels of the locomotive by the coefficient of sliding friction of the steel tire of the drivers on the steel rail. Modern practice uses 0.20 as a safe coefficient. The Master Mechanics' Association considers 0.21 as the correct coefficient, and that this may be increased to 0.25 by a good sanding apparatus. Therefore the tractive power of a locomotive is 1-5 its total weight on its drivers, This is its "pull."

The boiler power of a locomotive is more exactly defined as steaming power. The amount of grate surface upon which fuel may be burned, and the amount of heating surface by the use of which steam may be generated are the factors in boiler power. Obviously the grate surface and boiler surface are somewhat limited in a railroad locomotive. This is the power due to surface,

Transmission power is the factor of least moment in our

problem, because it is not a controlling factor. It is the power exerted by the moving parts—piston, driving-bars, etc.—in transmitting the force of the steam from the boiler to the circumference of the driver, and therefore to the draw-bar of the locomotive. This transmission power is often termed the cylinder power. Of course, the strength of the other driving parts is readily adjusted to the force of the cylinder.

Since the tractive power is limited by the weight upon the drivers, and the boiler power is limited by either or both the grate surface and the heating surface, we can not use either of these forces as a measure for the size or power of a locomotive without considering the other. But the transmission force is not so limited. The cylinder measures this force. The cylinder is intermediate between the boiler and the point of adhesion of the drivers on the rail, and there is room for this cylinder to be of any needed size which the boiler power or weight on drivers may require. We may, therefore, measure the power of the entire locomotive by the size of the cylinders, since the manufacturers do likewise. This is the custom. We speak of a locomotive as an "18x24"—meaning an engine having a cylinder 18 inches in inside diameter and of a length of cylinder to give a 24-inch stroke for the piston. Frequently the length of stroke is disregarded in speaking of the size of an engine and the diameter of the cylinder alone is mentioned. An 18x24 in. cylinder is termed an 18-in. cylinder, or we may say an 18-in. engine. Some roads "over-cylinder" their engines, i. e., give engines a larger cylinder than is necessary for the adhesion or the heating surface of that engine. But this practice is seldom used by any road, save for passenger trains, to help them start quickly. We need not consider this practice, because it is the freight engines for which maximum grades and curvature associated with them are usually to be adjusted.

GRATE AREA.

The amount of grate surface needed depends upon the amount and kind of fuel to be burned per hour. It is conceded that for each kind of coal there is a maximum number of pounds that may be burned for each square foot of grate surface to give the most economical results. A certain depth of fire on the grate is economical with one kind of coal while a different depth of fire is economical with another kind of coal. A coal requiring a thinner fire therefore demands a larger grate. Certain engines have been built to burn refuse coal. As this coal is usually fine coal, slate and earth, the engines are termed "Dirt Burners." Each merchantable steaming coal has its peculiar qualities which affect the action of that coal when burning on a locomotive grate. This fact makes new coal dreaded by locomotive firemen until they become acquainted with the firing qualities of the coal. Of late

years the demand upon locomotives has increased so rapidly that more skillful firing and larger grates have become imperative. We now have firemen to instruct those firemen who are not familiar with their coal. To increase the grate surface sufficiently has been, and still is, one of the problems in locomotive design. We early had in this direction the wide fire-box of the Wootten type, named for the designer.

Expressing the grate area in terms of the cylinder of the locomotive we may say[1] that for each cubic foot of volume of the cylinders there should be 3 sq. ft. of grate area when bituminous coal is used. This ratio should be increased to 4 sq. ft. of grate area for large anthracite coal, and to as high as 9 sq. ft. of grate area for small anthracite coal for each cubic foot of cylinder volume. In general it may be said that from 60 to 100 lbs. of coal may be economically burned per hour on one square foot of grate surface. One square foot of grate surface is assumed to be required for each 600 lbs. of tractive power the engine might exert. While no such statement can be exact, it is approximately true that engine grates now are from 36 to 42 ins. wide and from 72 to 144 ins. long. In a general way it may be said that the depth of fire used on these grates for an economic use of our coal is about 20 ins. for bituminous coal and 9 ins. for anthracite coal.

THE BOILER.

The heating surface is in the boiler and fire box; about one-tenth of this surface being in the fire-box. The locomotive boiler is not a water-tube boiler, but heated gases from the fire-box pass through the tubes. The outer surface of the tube is the surface to which the water is exposed and is therefore the heating surface. The diameter of each tube in the boiler should bear a certain ratio to the length of that tube. It is considered that it is best to make the external diameter of a boiler tube 1-70 to 1-90 of its length. In practice, a boiler tube is ordinarily about 2 ins. outside diameter. The boiler tubes are not placed nearer than 2 ins. to the boiler shell as a rule. But the distance between the top row of tubes and the boiler shell is about 1-4 the diameter of the boiler shell. It is found that about one square foot of heating surface is required for 10 lbs. of tractive power. In general one pound of coal burned upon the grate surface will evaporate six pounds of water into steam at the boiler or heating surface.[2]

For each cubic foot of cylinder volume there is required 180 sq. ft. of heating surface, if large anthracite coal is used, and 200 sq. ft. for heating surface if small anthracite or bituminous coal

[1]See Proceedings American Railway Master Mechanics' Association for 1897, p. 230.

[2]See Proceedings American Railway Master Mechanics' Association for 1897, p. 230.

is used. In all cases it is recommended that the fire-box heating surface be 10% of the total heating surface.

In recapitulation we may say that a locomotive has a tractive power of 1-5 the weight upon its drivers. This is the draw bar pull in front of its tender. That for each 600 lbs. of tractive power or draw-bar pull there must be one square foot of grate surface. That there should be 40 to 60 sq. ft. of heating surface for each square foot of grate surface, varying with the kind of coal used. That the size of the cylinders should be such that for one cubic foot of cylinder volume there shall be from 3 to 9 sq. ft. of grate surface, and from 180 to 200 sq. ft. of heating surface, varying with the kind of coal used. All of these proportions are true for simple engines, but for compound engines these proportions differ.

ENGINE RATING.

On most roads at the present time there is a tonnage rating of engines. This is either shown on the employee's time card or placed on a special bulletin. The following is a locomotive rating-sheet in tons for a part of a division of the C. & N. W. Ry.

CLASS OF LOCOMOTIVE.			C-5	D-1 A	S-3	S-2
Dimension of Cylinders.	16 x 24	17 x 24	18 x 24	18 x 24	18 x 24	19 x 24
Winona and Lewiston................	160	195	240	275	290	385
Winona and Lewiston, Double........	545	580	625	660	700	780
Lewiston and Rochester, Run Eyota...	520	615	765	825	860	1030
Eyota and Rochester.................	430	520	640	690	725	860
Rochester and Byron.................	315	385	460	500	525	630
Rochester and Owatonna, Double Byron.	535	630	780	840	875	1045
Owatonna and Waseca..............	590	725	880	950	1000	1200
Waseca and Mankato................	565	690	840	905	950	1135
Mankato and New Ulm...............	720	875	1065	1145	1200	1435

The above rating applies under ordinary conditions of track and weather, and over the maximum grades between points indicated, but does not include caboose or engine. Additional tonnage will be hauled wherever engine can handle it.

The rating from Winona to Lewiston, double, is figured on the basis of 19x24 helper engine. When smaller helper engine is used the combined rating of both engines will be taken.

Fifteen per cent. more than rating can be hauled Traverse to New Ulm.

Three hundred tons additional can be hauled Lewiston to Winona.

Conductors will report gross tonnage out of Eyota, Rochester, New Ulm, and into and out of Mankato, in both directions.

All trains when consisting mostly of empty Stock cars or empty Box cars will run ten per cent. light.

All Stock trains and time freights will run ten per cent. light.

The best practice is first to compute the engine rating and then test it by an actual trial. To do this for every engine on all parts of the division where it is used is too much work and expense. Engines of the same class must be assumed to merit the

same rating. The rating of a locomotive may be calculated from the tested rating of one differing little from the one tested. All of this work in locomotive rating takes time and intelligent care. Thus far many inconsistencies have been shown, but the tonnage rating has increased the average train load hauled.[1] It has been proven that the former practice of requiring an engine to haul so many "loads" was a lax system compared with requiring that engine to haul so many "tons" of train weight. Usually the tonnage rating of engines, when given on time cards or elsewhere, is the load when the train is made up of loaded cars. As seen in the time card rule, the C. & N. W. Ry. deducts 10% from the tonnage rating of an engine on the time card whenever the train consists entirely of empty cars. The practice in this respect varies with different roads.[2]

Instead of some percentage reduction for a train of empties, or rating empties at a different rate from their actual weight, it is practicable to rate an engine for a different tonnage for the different numbers of cars hauled. The following tonnage rating of the freight engines of a part of the Galesburg Division of the C., B. & Q. Ry., issued January 1, 1902, is a case in point:

GALESBURG TO CHICAGO.—Class R-2 Simple Engines.

"A"		"B"		"C"	
No. Cars	Tonnage	No. Cars	Tonnage	No. Cars	Tonnage
95	1000	101	1200	90	1760
81	1005	80	1225	87	1775
62	1030	70	1250	85	1790
52	1055	62	1275	81	1805
46	1080	58	1300	81	1820
41	1105	53	1325	79	1835
38	1130	50	1350	77	1850
36	1150	47	1375	75	1870
33	1175	45	1400	74	1890
30	1200	43	1425	72	1910
		42	1450	70	1930
		37	1500	69	1950
				68	1975
				66	2000
				65	2025
				64	2050
				63	2075
				62	2100

"A" Meat Trains. "B" Stock Trains. "C" Dead Freight Trains.

For the above rating the writer is indebted to W. B. Throop, C. E., Supt. of the Chicago Div. of the C., B. & Q. R. R.

[1]For report of committee on tonnage rating of locomotives see Proceedings of American Railway Master Mechanics' Association for 1898.

[2]See Proceedings American Railway Master Mechanics' Association for 1898 for an excellent report of a committee on tonnage rating.

The tonnage rating as given always presumes the rails of the track to be in good condition, i. e., dry and not frosty. The Great Northern, a pioneer road in the tonnage rating of engines, makes the following percentage reductions:

7% reduction for frosty or wet rail.
15% reduction for freezing to zero temperature.
20% reduction for from zero to minus 20°.

It seems better to leave such reductions for weather to the Superintendent's office. The whole question of the tonnage rating for freight locomotives is not to-day fully and thoroughly established. Much work has been done but more is needed to fairly, intelligently and economically rate our engines. Still, enough has been done already to show considerable gains in earnings through larger average train loads hauled at commercial speeds.[1]

TRACTIVE POWER.

The Tractive Power, or Tractive Force, or Traction (the terms are synonymous) of a locomotive is the amount of pull it can exert on the draw bar in front of its tender. It may be determined in three ways:

(1) By computation from the dimensions of the engine and the boiler pressure;

(2) By computation from the weight of the engine resting on the driving wheels and the co-efficient of friction of the driving wheels on the rails;

(3) By test, either by observed pull in dynamometer or by weighing the maximum train.

But locomotive resistances are of two kinds—internal and external. A locomotive is both a machine and a carriage—a stationary engine and a railroad car. As a machine, the locomotive has those resistances due to friction of its moving parts, such as driving bars, valves, and links. The locomotive as a steam driven machine has the losses of efficiency due to the boiler pressure being effective through a part of the stroke, and losses due to wire-drawn steam and to back pressure. All these resistances and losses of the locomotive as a machine we recognize in this connection, but we do not take them into account because they do not concern the location engineer. These losses due to using steam and due to friction of the moving parts of the engine, can be overcome by increasing the grate, boiler and cylinder sizes, and without affecting the tractive power. They are scarcely affected by change of route, and should be a percentage reduction.

By tractive power we mean, in this instance, a certain less amount than the total tractive power, therefore, of the formula.

[1]See "Economic Theory of Railroad Location," by A. M. Wellington, Table 170, for a valuable pioneer table on tonnage rating.

By the first method, the Tractive Power is computed by means of the following formula:

$$P = \frac{d^2 lp.}{D}$$

P=tractive power.
d=diameter of cylinder in feet.
l=length of piston stroke in feet.
D=diameter of drivers in feet.
p=boiler pressure in lbs.

This formula is the mechanical engineer's formula, and presupposes that the engine dimensions are rightly proportioned, and in good working condition.

The second method of determining tractive power is by means of the weight on the drivers multiplied by the coefficient of friction. While the above formula is the general one for computation of tractive power of any locomotive, it is better to use simpler units. The weight on the driving wheels forms a better basis for computation. The relation existing between the weight of the engine and the tractive power cannot be overlooked by the locating engineer. He must leave the proper design of the locomotive to the mechanical engineer, but the locating engineer has a right to expect that the engine is so proportioned that it will exert a tractive force proportionate to its weight on its drivers. At the same time, it must not be forgotten that the total weight of the engine is a part of the train weight. The relation between weight on drivers and tractive force of a locomotive varies with the conditions. A dry, bright rail, free from frost is assumed as the normal condition. Under these conditions, the tractive power is one-fourth the weight on the drivers, i. e., the coefficient of friction is then 0.25. Obviously, the hardness of the rail and the engine tires must be considered. The writer has seen one of the heaviest mountain engines which had never pulled the loads of its class simply because its tires were too hard. In practice we can only assume average hardness for tires and rails. The use of sand on the rail increases this tractive force one-third or more of the weight on the drivers, while a rail wet from rain, greasy from fog, or icy from frost decreases this tractive force at least one-fifth the weight on the drivers. If the road is for fast freight and passenger business, mainly, a reduction of the working tractive force must be made for speed. This speed reduction is arbitrary and is about 10% for twenty miles an hour.

Finally, while it is a law with every teamster in the world that the farther his team is from the center of his loaded wagon or wagons, the less his team can pull, engineers of railroads did not discern this fact. Rating engines by tons and not by carloads has caused this law to be recognized in some instances. The earliest allowance for this the writer has ever seen is given below. It is

by Mr. J. O. Pattee, former Superintendent of Motive Power, Great Northern Railway—a road that has done, and is still doing, much pioneer work in systematic and intelligent study of engine performance and cost of transportation of traffic.

We quote from an excellent paper, entitled, "The Hauling Capacity of Locomotives," by Mr. H. H. Vaughan, Mechanical Engineer of G. N. Ry., published in Trans, Northwest Railway Club, December, 1895.

"For an operating division having no curves sharper than 6°, add to the calculated rating of each engine 6 tons for each **loaded** car in its train. This increases the numerical rating of the engine (by e. g. 6 tons x 50 cars equals 300 tons) and gives a rating beyond the capacity. When making up the train add to the actual weight of loaded cars 6 tons. If the train be all loads, the number of cars (and actual tonnage) will not be changed by the rule. But, when making up a train having empty cars, in part, add 6 tons for each empty. In other words, you consider the tractive power necessary to haul an empty car greater per ton than a loaded car. If the train be made of empty cars only, the train by this rule will be about 25% less in weight (and length) than it would be otherwise. Where curves exist sharper than 6° use 8 tons, or even 10 tons, instead of tons as above."

This rule recognizes the fact that length of train has in itself a resistance. It is a fact which writers on mechanics have not recognized. It seems to be another instance added to a long and lengthening list, where the locomotive engineer has taught the civil engineer better railroading. The rule given is open to the objection, not a serious one, that it gives to the engine a fictitious tonnage rating.

Mr. Tracy Lyon, Master Mechanic, Chicago & Great Western Railway, in a paper read before the Western Railway Club, Chicago, gives it as a rule in use on his road that for a full train of empty cars the engine rating is reduced 10%. For a train having a part of its cars empty, a proportional amount of the 10% is deducted from the engine rating for that train. Both of these rules are empirical and their value depends on how closely they accord with observation. They are most welcome, but all will agree that more light is needed. The condition and temperature of the rail has been found to necessitate a reduction in tonnage rating. To that system of rating is due an estimate of these reductions. Sufficient data have not yet been secured. It is safe to say, probably, that a wet rail—due to rain or fog—lessens the coefficient of friction between the wheel and rail about 5%. Some roads do not recognize this unless the rail is "greasy" from fog as well as wet. However, we shall say that for a wet rail reduce the rating 5%; for a frosty rail reduce the rating 8%; for a rail in a temperature of air from 32° to 0° reduce the rating 15%; for a rail in an air temperature

of 0° to 25° reduce the rating 20%. These percentages must be considered as suggestive, and vary from those of the G. N. Ry., given above.

Before dismissing the subject of tractive power by considering the weight on the drivers multiplied into a coefficient of friction, and from which percentage reductions are made, we must revert to the fact that an engine has a working percentage of efficiency. A driving wheel has not always its full weight upon it. Poor coal, bad water, a neglect on the part of the fireman, even when the engine is doing fairly good work, will reduce the efficiency. Most engines are "over cylindered," i. e., have cylinders so large they will use steam faster than the boiler can produce steam. This is especially true of engines designed for a division between "mountain" and "plains or prairie" divisions. An engine can then pull more for a short distance than it can pull for a long distance. Again, we are obliged to say that the data are insufficient; but a beginning has been made. The reduction varies from 5% on an easy division, having light gradients and short maximum grades, to 20% on a division with difficult gradients and long maximum grades.

According to Mr. H. H. Vaughan, Mechanical Engineer, G. N. Ry., "80% is the rating adapted for long, steep grades, such as those on the western end of the line (Cascade Mts.), where the engines are worked hard for a considerable time and the limit is imposed by the rate at which coal can be burnt if the fire is to be kept in proper condition. On grades not exceeding five or six miles in length, a rating of 85% may be adopted, or on long grades when the quality of coal used will admit of more rapid combustion. In some cases we have been able to adopt a rating of 90% for long grades, but this has been where coal and water have been both favorable, and this rating is generally used on undulating track where the maximum power is required for short distances only. A rating of 92% has been used where the limiting grade on a section of road has been short, and a majority of the line easier, and has given reliable results in such cases, even though the train had to be started on a grade."

These modifications and reductions from the amount of the product of the weight on the drivers multiplied by a coefficient or friction for the amount of the traction power are contributions to the locating engineer by the locomotive engineer and the motive power department. To the study of tonnage rating they must be largely credited.

"Tonnage" rating and not "loads" rating is desirable. The Great Northern Railway is far advanced along this line of improvement. This road now holds the world's record for lowest cost of moving freight per ton per mile. The Kalispell Division rating sheet is the one selected, as showing greatest diversity in rate of ruling grade. To those less familiar with the subject

of rating, the great differences in what the same engine is able to haul over gradients not so very widely separated is quite striking. Notice that the same engine on the same ruling grade but at different points has a quite different rating. Unequated curvature, length of the ruling gradient, a small obstacle offered by virtual profile probably account for these variations. This rating sheet was furnished by former General Superintendent Russell Harding of the G. N. Ry., now Vice-President of Mo. Pac. Ry.

GREAT NORTHERN RAILWAY.

Capacity of Different Classes of Engines in Tons, in addition to Weight of Engine, Tender and Caboose.—1898.

Kalispell Division.

Stations.	Ruling Grade	19 x 32 200 lbs	20 x 26 180 lbs	19 x 26 180 lbs	19 x 24 180 lbs	19 x 24 150 lbs	18 x 24 145 lbs	17 x 24 145 lbs
Blackfoot to Summit....	1.0	900	825	725	650	575	460	416
Summit to Belton.......	Down							
Belton to Kalispell......	.6	1600	1350	1250	1150	1000	830	745
Kalispell to Essex.......	.8	1050	950	875	800	700	590	540
Essex to Summit........	1.8	525	475	440	400	350	255	232
Summit to Elk.........	1.0	1025	925	850	775	650	550	530
Elk to Blackfoot........	Down							
Kalispell to Haskell Pass.	1.5	675	600	550	485	420	310	280
Haskell Pass to LakeView	Down							
Lake View to Melbourne.	1.0	1035	925	875	800	675	460	416
Melbourne to Bonner's Ferry................	Down							
Bonner's Ferry to Naples	.97	1050	950	900	825	700	600	490
Naples to Elmira........	.75	1300	1200	1100	1000	900	800	590
Elmira to Morse........	.7	1425	1300	1200	1100	1000	900	670
Morse to E. Spokane....	1.0	1050	925	875	800	675	575	485
E. Spokane to Newport..	0.6	1360	1250	1150	975	870	725	640
Newport to Troy........	0.6	1650	1500	1400	1300	1100	950	860
Troy to Jennings........	.75	1420	1300	1200	1100	1000	900	615
Jennings to Haskell Pass.	1.5	675	600	550	485	420	310	280
Haskell Pass to Kalispell.	Down							

The Third Method of determining the tractive power of a locomotive is by dynamometer test, or by weighing the train. To-day, however, the dynamometer is little used. It is placed between the engine tender and the forward car of the train and indicates directly the tractive power at that point. Tests of this kind are at least needed as a check upon engine rating obtained in other ways. The dynamometer reading gives at once the tractive power of a known load on a known gradient or curve and it is a basis of direct comparison of operating divisions, or of parts of the same division.

At the present time, weighing a train and watching an engine in good order and under known conditions pass over a certain

part of the road is the usual method of measuring and using tractive power in engine rating. This plan is open to criticism. Most locomotive engineers will say that it rates engines too high in working-load for average weather, fuel, etc. But it is practical, and it is used by all or nearly all the motive power departments which are making progress in engine rating, and showing gains in engine performance. If the locomotive engineer is correct, the shorter "expectation of life" of his locomotive will show it in the future. While the opinions of all locomotive engineers cannot be heeded, the writer must always plead guilty to a tendency to listen to the locomotive engineer on questions of train resistance. The locomotive engineer has given locating engineers the virtual profile; and the writer has learned by experience that the locomotive engineer and the road master are two men whom a civil engineer must be chary of contradicting.

By repetition, and through the careful attention of the mechanical engineer, or of the motive power department, rating for each class of engine is made on a certain division. This rating may be modified for those engines on another division having different grades.

To recapitulate: We can say that, by the second method, tractive power is computed under various conditions and deductions made from it as follows:

Tractive power on a dry, bright rail, free from frost, equals 20% of the weight on the drivers. Tractive power may be, under these conditions and a sanded rail, increased to as much as 33% or possibly 40% of weight on the drivers. The use of sand is practically the only way of increasing the coefficient of friction. The use of traction increasers, which shift most of the load from the truck to the drivers, is not now common.

The deductions from the tractive power under normal conditions, i. e., 20% of the weight on the drivers, are:

For wet rail, deduct 5% from computed tractive power.

For a frosty rail, deduct 8% from computed tractive power.

For a rail in air temperature 32° to — 0°, deduct 15% from computed tractive power.

For a rail in air temperature 0° to — 25°, deduct 20% from computed tractive power as a correction for engine efficiency.

As a correction for engine efficiency:

For easy grades and short maximum grades, deduct 5% from computed tractive power.

For easy grades and 6 miles maximum grades and good coal and water, deduct 10% from computed tractive power.

For grades not over 6 miles deduct 15% from computed tractive power.

For difficult grades and long maximum grades, deduct 20% from computed tractive power.

As a correction for train length[1]—for a train of empty cars deduct 10% from the computed tractive power; for trains of loads and empties deduct proportionately.

A clearer conception may be had of the amount of draw-bar pull an engine may exert by considering the engine to be suspended in the air entirely clear of the track, but in all other respects in its normal position. For simplicity we consider but one side of the locomotive, and instead of several drivers on each side let us assume but one driving wheel. This would be the "grasshopper" engine sometimes seen as inspection engine or used in pulling pay cars. It is readily seen that the mechanical laws are the same for one side of a one-driver locomotive as for both sides of any engine of any number of drivers. Now, for our flanged driving wheel, substitute a belt wheel of equal diameter, put a belt on this wheel and run it to a receiving pulley placed on a line shaft. This locomotive is now a stationary engine with a certain boiler pressure and a fly-wheel of the size and periphery speed of the locomotive driving wheel. The pull it exerts on the belt is the amount of tractive force the engine would exert at the rails, i. e., one-fifth the total weight on the driving wheels. As the speed of the stationary engine varies the belt pull varies. And this belt pull measures the power of the engine if we add to it an amount to cover the losses due to friction and other causes within the engine itself. This amount is what we allow for internal friction in a locomotive, and is considered by Mr. Wellington and others to be 10% of the locomotive power.

THE TRIPOD SUPPORT.

Probably the most distinctive feature of the American locomotive is the tripod support. The merits of such a support scarcely need be insisted upon with civil engineers, as it is the form of support of their field instruments. With but three points of support each of these points must always bear some part of the load unless the load be on the point of over-turning. With four or more points of support, one or more may be carrying no load. The moment this becomes the case the tractive force of the locomotive is reduced and undue strains are placed on some parts of the machinery. The tripod support makes an American engine have a greater draw-bar pull than other types of engine in proportion to its weight on the drivers.[2]

The tripod support was brought about by two devices: the

[1]While this deduction is not one the locating engineer needs to consider, and is pertinent to tonnage rating rather than to locomotive resistance, it is a proper percentage in tonnage rating of the tractive power of an engine.

[2]The feature of the tripod support is distinctly shown by "The straight line engine," built by John E. Sweet at Syracuse, N. Y. It is a stationary engine needing no carefully prepared bed.

forward truck of the locomotive, and the equalizing levers of the driving wheels. Our first engines were bought in Europe and had no front truck. There were no wheels in front of the driving wheels. Mr. John B. Jervis, one of the pioneers of railroad engineering in this country, who belonged to that period when mechanical engineering was a part of civil engineering, designed the front truck. This was in the year 1834. His object at the time was to give greater safety to our engines on the then very rough tracks by putting a little of the weight on a four-wheeled truck ahead to guide the engine around curves and steady the engine from plunging. That this truck in front of the drivers of an engine was at first called a "pilot" is an indication of its purpose. It is now called the engine truck. The pilot is a term applied to the lattice work or fender popularly known as the cow catcher, probably because it was to keep cows from being caught. The engine truck was originally a four-wheeled truck attached by a pivoting bearing to the engine proper. The axes of the truck were turned by the curving rails so that the axes were radial to the curves as the various curves were passed over. This not only decreased the flange friction, but tended to turn the engine frame in the direction of the curve. Load enough is put upon the engine truck for guiding purposes. Five tons is a common total load on a truck. Too much weight on the truck lessens the tractive power of the engine by reducing the total weight on the drivers. It was soon found that a pivoting truck was not flexible enough for our sharp curves, and the bolt instead of acting in a round hole was provided with a lateral slotted hole. This gave more lateral movement and allowed the path of the pivot to follow a line between the curve and the tangent to the curve at the center of the engine frame. But as engines were made heavier in later years their boilers had to be lengthened to give more heating surface. Longer boilers demanded longer engine frames and longer wheel bases. The engines then inclined to bind in their flanges between the rails on sharp curves. If the truck pivot could be given even more lateral motion than the slotted hole provided for it would lessen resistance and add to safety. To do this a rocker attachment was devised. (Fig. 36.)

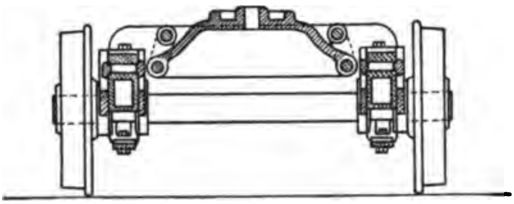


Fig. 36.

Essentially this is four small eye bars moving freely on pins at each end and forming a swinging support for the part of the engine carried by the front truck. It is a swinging bolster. It has more lateral motion than a slotted hole truck and moves with less friction and is more sensitive.

We have spoken of four-wheel engine trucks. A truck may be two-wheeled. The Mogul engine was designed with a two-wheeled truck. Such a truck gives a shorter total wheel base. Some consolidation engines have two-wheeled trucks. This single truck is less in favor now than formerly. They are thought to be less safe, as they slew around more easily when off the rails and increase the damage done in a wreck. The rocker attachment of the truck to the engine frame has made a two-wheeled truck less needed than heretofore. Engines for any class of fast service now use, as a rule, the four-wheeled truck. The engine truck forms one of the three points of the tripod support.

EQUALIZING BARS.

The equalizing bars are the second distinctive feature of American engines, and the points where the system of these bars on either side of the engine attaches to the engine frame form the two remaining points of the tripod support. The equalizing bars were first designed and applied by Mr. Ross Winans. As in the design of engine truck, the rough track we then had in this country gave the incentive to the design of the equalizing bars. To

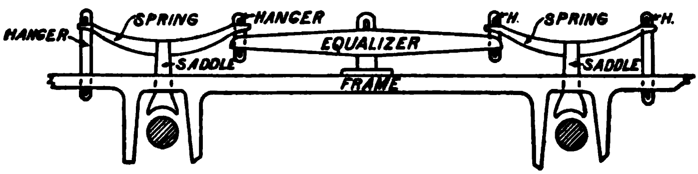


Fig. 37.

place the engine frame immediately upon the driving axles gave poor results at low spots on the rail and caused extreme jolting at considerable speeds. The equalizing bars were to increase tractive force and give smoother riding qualities to our engines. (Fig. 37.)

As is seen, these equalizing bars form a system of levers attached to one point of the engine frame on each side, and ultimately each journal of the drivers is attached to the other ends of the levers. The effect is to have some part of the weight on each driver at all times, however rough the track or uneven the superelevation of the track. Some types of engines cannot use a complete equalizing lever system.

Another distinctive feature of the American locomotive is the fact that it is outside-connected, while the European locomotive is inside-connected. The main rods and the driving rods are outside the drivers instead of inside them as in foreign locomotives. The difference in the appearance of the locomotives from this cause is marked. The rods and their bearings are more accessible for inspection, oiling and repairs on our own engines. The cab

of the American locomotive is longer and more roomy, and therefore gives better accommodation for the engineer and fireman and affords more protection from the sun and storms. Our long runs and possible delays on the road, together with our severer climate, make our cabs more necessary here than it would be in most parts of Europe. The tendency is now toward cabs giving an engineer better protection on locomotives of European manufacture.

CONCLUSIONS.

We may recapitulate as follows those questions relative to locomotive design and performance which must be taken into account in railroad location. The tractive power of the different classes of road engines owned or desired by the company must be learned. This may be done by computation or by reference to their tonnage rating in practice. A good method is to compute the tractive power and then test the engine and see how it hauls this computed maximum tonnage. Caution is now needed in this matter, for tonnage rating of locomotives is not well enough understood to avoid error when applying theoretical or mechanical deductions to railroad transportation practice.

In general, an intelligent allowance must be made for proposed maximum gradients and for all curvature, especially when occurring on grades at or near the maximum gradient. In locating a line when the country changes at a certain point, and a change in the rate of maximum gradient is desirable, this change in rate of maximum gradient must conform to the different classes of the locomotives. It is usual to increase or reduce the gradient so as to require either the next heavier or next lighter class of locomotive. The common error of the locating engineer is to change the rate of maximum gradient so little he needs an engine of a class intermediate between existing classes. Use a certain maximum gradient or use another one. Do not merely vary from one, but change as sharply and as much as the classes of engines change.

A long hill on a maximum gradient is an entirely different question from a short hill on that gradient. To increase slightly the length of an already long hill on the maximum gradient is a serious matter and should by all means be avoided whenever practicable to do so. To put a little sharper curve at the top of the long hill than is used farther down, where no curve is "equated for," is an unpardonable blunder. For the long hill has taxed the whole tractive power of the engine so fully and so long that the boiler pressure has run down and the speed slackened until there is no reserve force to meet the added resistance, and the engine stalls. It is fatal to add even a trifle to a maximum load. A "letup" by getting some minor gradient in the middle of a long hill is very wise. A locating engineer must keep in close touch with the locomotive engineer in these matters.

CHAPTER VII.

PART I.

Train Resistances.

We shall first consider train resistances, including all car resistances, all resistances due to engine tender and engine truck, and all resistances due to engine drivers rolling along the rails. We shall consider separately the resistances due to velocity of train, velocity of wind against the train, and resistances due to oscillation, as this last is clearly a velocity resistance also. Finally, we shall consider the resistance due to inertia.

Many railroad men and writers on railroad topics forget that an engine is part of the train, and that a part of its resistances are purely train resistances. The engine tender is purely a car of the train hauling non-paying freight, consisting of coal and water. The engine truck, or "bogie," is a car pushed ahead of the engine, on which the front end of the engine lightly rests in order to steady the engine on rough track and guide the engine more gently and safely around curves. All of these resistances of the locomotive are a tax upon the tractive power or "adhesion." Other engine resistances, such as friction of driving bars, normal friction of drivers and steam losses and resistances are a tax upon the firebox, boiler and steam cylinder, but not a tax upon the "adhesion" of the drivers to the rail in resisting slip.

JOURNAL FRICTION.

Journal friction comprises: (1) Journal friction of each journal of all cars of the train; (2) the friction of all journals of the engine tender and engine truck or bogie. Obviously, this journal friction is the percentage of the load on each journal, whether it be a car, tender or truck journal. We need to know the coefficient of journal friction and apply it to the entire weight of cars, tender and load on engine truck. We exclude the weight of the engine on the drivers. Here, as in so many similar problems, we are confounded by the fact that too few experiments have been made. Two-thirds of a century ago M. Morin laid down some simple laws from a very few experiments; though he never intended that much reliance should be placed upon his conclusions.[1]

[1]Morin's laws are: (1) The coefficient of friction is independent of amount of surface in contact; (2) Independent of unit pressure; and (3) The coefficient of kinetic friction is independent of velocity. These laws justified such rails as the Fritz-Sayre type, with large contact surfaces which practice has shown to be wrong. These laws have been largely disproved—notably by Westinghouse who showed that velocity affected the coefficient of friction.

The "brake" tests and various "drop" tests of cars would, of course, include both journal and rolling friction, and their results do not answer our purpose. The results are all termed rolling friction, but it is probable that more than half the resistance is really due to journal friction. As the results are used by the observers in engine rating it is immaterial whether the result of a "drop" test is journal friction or rolling friction proper, as the summation of these two resistances is the thing sought. A series of laboratory tests with full-sized car journals is needed.

From the best data now available, it may be said that the journal friction is about 4 lbs. per ton, or 0.20%. The writer is of the opinion that this percentage is more apt to be too large than too small. It is not necessary to dwell upon lubrication which affects this coefficient of friction. Average conditions are assumed. Temperature modifies it also, low temperature materially increasing it, while extremely high temperature also increases the friction. Velocity affects this resistance. Usually, a train has its least journal friction at about twelve miles an hour; while a slower speed or a higher speed will increase the journal friction. We scarcely need to consider the increase due to high velocity, for the increase is not great for a train at twenty miles an hour—the ordinary freight speed. To assume a less speed than ten or twelve miles an hour is never desirable in designing a road.

ROLLING FRICTION.

Rolling friction comprises the friction of all wheels arising from their rolling along the rails. The rolling friction is computed for the entire weight of trains, including total weight of engine. Here, also, there is a dearth of data for safe estimate. The percentage of the total train weight to be taken for rolling friction can only be found by experimenting with a train; since the rail is a continuous girder supported by the ties, and the deflection of the rail, when the wheel is supported by the rail at a point between ties, will vary as the stiffness of the rail changes. The much heavier rails now used lessen the rolling friction of a train. Rolling friction now appears to be less than past experiments show.

We may assume from the best data we have, that the rolling friction is not over 0.15% of the total train weight, or three pounds per ton. We now have for total train resistance:

Journal Friction = 0.20% = 4 lbs. per ton.
Rolling Friction " 0.15% " 3 lbs. " "

or a total of 0.35% = 7 lbs. per ton for journal and rolling friction. Brake tests gave us heretofore about 8 lbs. as a safe maximum; later we have been led to consider 7 lbs. as safe for starting trains; and it is known that this resistance is often as low as 4 lbs. per ton for trains in motion under favorable conditions. Some authorities use 6 lbs. as justifying their engine rating. Better journal boxes,

better lubricants, more uniform wheels and heavier rails now tend to reduce actual observed journal and rolling friction. Seven pounds per ton, or 0.35% of the train weight in tons, is now a safe maximum, although a further reduction is pending. This frictional resistance is evidently equivalent to overcoming a 0.35% gradient; hence we may say that even on a level track a train is practically running up a 0.35% grade.

VELOCITY RESISTANCE.

The velocity resistance of a railroad train is the resistance that the air offers to the passage of the train, plus the resistance due to oscillation caused by the rapid passage of the train over the rails. This does not include starting resistance. It is usual to consider the air resistance and the oscillation resistance together. It is difficult to separate them, experimentally, so the unit allowance includes both. These oscillation resistances do not include those due to badly surfaced tracks or excessive widths of gauge. They include oscillations due to speed, only, on average tracks. They include the oscillations known as "wandering" of the locomotive, running against one rail for a distance, then swinging over to the other for a time. The gauge of the track must be greater than the gauge of the wheel tread, and "wandering" results.

By this is also meant the so-called "hammer blows" of the counterbalancing members of the engine and all impact due to the action of springs. These should not exist in any great amount; but we must consider velocity resistance to be all resistance caused by velocity, i.e. those added resistances which increase the demand upon the locomotive by reason of high speed. It has been found that the least demand upon the locomotive is when the train has a speed of about ten miles per hour. We consider, therefore, that velocity resistances are non-existent at ten miles or less per hour.

Air resistances, unlike oscillation resistances, can be measured by trials, or in a laboratory, and they are more or less comparable with wind forces or even water forces.[1] We do not know that the action of air in motion against a fixed surface is exactly like the action of air at rest on a surface moving at a velocity through it. The writer wishes to call attention to this fact. The formulas true for a windmill may not be true for an express train. Early experiments were made with thin plates. Weisbach (Sec. 511), and old formulas presupposed such bodies without length. A car has length and to it those old formulas do not apply. (Weisbach, Sec. 512.) There does not seem to be sufficient proof that a whirling body in a definite space is safely analogous to a train; and it is probable that the laws of resistance offered by air to the passage of bodies

[1]See Weisbach's Mechanics, Sec. 511, where the impulse of air or water against a plain surface at rest is shown by Buat and Thibault to increase by a coefficient of 1.86; but when that surface is in motion through still air or water that coefficient reduces to 1.25.

are not the same at high as at low velocities. A formula true for small surfaces gives excessive resistances for large surfaces.

Prof. Francis E. Nipher, of St. Louis, learned that for a board 3 × 4 ft. the resistance or pressure at the center, was double what it was near the sides. (See paper read before Academy of Science, St. Louis, December 20, 1897.) This was found to be true at the Forth Bridge by Sir Benj. Baker. Care must be taken in reaching even probable conclusions. More experiments are needed; and our views upon velocity resistance of railroad trains, especially at the present high maximum speed of express trains, are in a state of revolution. There is a belief that we have overestimated this resistance because it is hard to see how some of our engines could well pull our trains at their daily speeds if our formula be correct. By some it is believed that we occupy now the position students of mechanics did some years ago when they said "curved balls" were impossible; but the pitcher showed the physicist that he actually pitched the ball in a curved trajectory, leaving the students of mechanical laws to find the reason for the fact. In velocity resistance of trains we can now only record the past beliefs and the present opinions, with the reasons for each.

The various velocity resistances of a train are as follows: (1) Head resistances of engine, cab, and forward car. This is the resistance of first disturbance of the air by the forward part of the train. (2) Intermediate resistances of successive cars, being subsequent disturbances of the air by the following portions of the train. (3) Tail or trailing resistances of the rear car (or caboose), which may be termed the suction resistance. (4) Oscillation, or impact due to velocity above ten miles an hour.

As air motors came before steam motors we naturally took our first formula for velocity resistances from the windmill; and about 1760 a formula came into use for the computation of the pressure on the air motor of wind at different velocities. This formula is as follows:

$$P = 0.005\ V^2,$$

where P is the pressure per unit surface and V the velocity in miles per hour.

While this formula is attributed to Smeaton, it is not certain that he was responsible for it. He probably used it with others. The important point of this formula is that air pressure varies as the square of the velocity. Who discovered this and how, we do not now know. While a formula in existence for one hundred and forty years is entitled to credence, it is well to remember that it was not intended for a railroad train, and that the surfaces exposed were thin surfaces, probably less in size than the front end of a car; and the velocities considered were generally lower than our fast trains. Again, a train has length, while a windmill blade had not.

The above formula has formed a basis for most of our formulas for velocity resistances of railroad trains. The most notable de-

parture from it, because of the repute of the author, is the formula given in Searles. Searles' empirical formula for velocity resistance of trains, given in his Field Engineering, p. 27, is as follows:

$$q = 5.4 + \left(.006 + \frac{.0006E^2}{E + W + T}\right) V^2$$

q = resistance to uniform motion in lbs. per ton
E = weight of engine and tender in tons
W = " " cars in tons
T = " " freight in tons
V = velocity of train in miles per hour.

This is stated by its author to be empirical, and to be "based upon a careful investigation of all such records of experiments on the subject, several hundred in number, as have come to the author's notice." This formula safely represents the best known facts then (1880) known on the subject.

Mr. Wellington used this formula, modifying its expression, only.[1]

It may be said in general that the European authorities adhere to the statement that air pressure varies with the square of the velocity; although at the enormous velocities of gunnery, some consider the pressure to vary as the cube of the velocity.

In 1890 Mr. O. T. Crosby, while experimenting for the Weems Electric Railway at West Point, N. Y., showed that velocity resistance of trains had been taken too large. (Engineering News, May 31, 1890, et seq.) He also considered that his results showed that the resistance varied not as the square of the velocity, as prior experimenters believed, but directly as the velocity, modified by a coefficient. This was a revolutionary statement. Crosby's experiments consisted in revolving bodies of one or two square feet area at the end of an arm 5½ ft. long, which was attached to a vertical axis 6½ ft. long. This shaft was driven by an engine, and the experiments were made in a room 40 ft. long, 13 ft. to 19 ft. wide and 12 ft. high. The roof extended to a still greater height of 7 ft., and there were open doors and windows. The conditions were not well comparable to a railroad train in the open air, on a straight track. The other experiment was with a car of 5.1 sq. ft. cross-section on a track of two miles in circumference. The car was propelled by electric motors and all tests were at about 50 miles per hour. This experiment is more like actual practice, but the car is small and but one velocity studied. The range of all the experiments, however, is found to be 130 miles per hour.

The deductions from Crosby's experiments are: (1) That resistance varies as the velocity modified by a coefficient and not as the square of the velocity; (2) that that coefficient is about 0.131.

Crosby's formula is:

$$P = 0.131\ V \text{ (instead of } P = 0.005\ V^2.)$$

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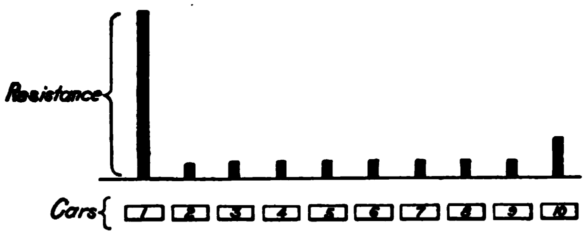
[1]Wellington, p. 523.

Mr. Angus Sinclair made some observations by indicator cards on the Empire State Express, N. Y. C. R. R., between New York City and Albany in 1892. (See "Locomotive Engineering" for June, 1892. An abstract of the article is printed in "Engineering News," June 9, 1892.) The train was the usual one, and all conditions were as in daily runs. Twelve cards were taken at the various conditions of duty, when getting up speed, when gaining speed, slightly, and when running at uniform speed. The highest speed was nearly 80 miles per hour, and the average speed about 50 miles per hour. Of course the result was in indicated horsepower, and not in pressure in lbs. per sq. ft. of surface, or per ton of load. It would appear that the total resistance of the train was about 19 lbs. per ton, average. But the individual cards do not show any more resistance when speed increases, e.g. from 69 miles per hour to 79 miles per hour. The experiment seems to need verification through repetition, in order to point clearly to an answer to the question of velocity resistance of trains.

In 1896 a series of experiments were made at Purdue University Engineering Laboratory. These results were embodied in a paper by Prof. W. F. M. Goss, read before the Western Railway Club in April, 1898.[1] Model cars 1-32 size of a standard box car were placed in an air-tight conduit 20 ins. square and 60 ft. long with glass sides. These models were eacn 12 1-16 ins. long, 3⅜ ins. wide and 4½ ins. high, while a box car is 32 ft. 2 ins. long, 9 ft. wide and 12 ft. high above the rail. The model represented a box car to a scale of 1 to 32.



Relative resistance offered by the several models of a ten-car train.
Fig. 38

A blower created a current of air at various velocities which were recorded by Pitot's tubes and a system of levers multiplied the movement of the model car and indicated it on an arc. The air velocities observed were from 25 miles to 105 miles per hour, and the observations were repeated many times. In different parts of the cross section the velocity varied much. The number of models was varied in different experiments from one model car to ten of them. The resistance of each car was taken. The results for a train of ten cars is shown graphically by Prof. Goss and given in Fig. 38.

[1]Through the kindness of Prof. Goss, Professor of Experimental Engineering and Director of the Engineering Laboratory, we are permitted to make extracts and use tables from his paper.

Pitot tube gauges showed the velocity of the air in the conduit. To each car was attached a very sensitive dynamometer to show the pressure exerted by the wind in the direction of the axis of the conduit.

The following were the results:

For the Pitot gauge	$R = 0.005\ V^2 + 2.$
For the only model	$R = 0.0012\ V^2.$
For the first model	$R = 0.0010\ V^2.$
For the second model	$R = 0.00008\ V^2.$
For the last model	$R = 0.00026\ V^2.$
For any intermediate model between the second and last	$R = 0.0001\ V^2.$

When R equals resistance in lbs. per sq. ft. and V equals velocity in miles per hour, the result is the total in pounds of the demand on the locomotive due to wind resistance.

The diagram is instructive. That air particles have inertia is clearly shown. The conclusion deduced from these experiments, when the relative sizes of the model cars and the standard cars are considered, is as follows:

For a standard box car, the resistance in lbs. of the first standard car of a train at a velocity of V miles per hour is

$$A = 0.099\ V^2.$$

For the second car of the train,

$$A = 0.008\ V^2.$$

For any car other than first, second or last car,

$$A = 0.010\ V^2.$$

For the last car of a train,

$$A = 0.026\ V^2.$$

These are surface and not ton resistances. How far are these experiments comparable with actual practice? That the relative results for different cars of a train are unique and interesting is self-evident. Early in his paper, Prof. Goss has used

$$P = 0.0025\ V^2, \text{ instead of } P = 0.005\ V^2$$

for his formula for pressure. He states that the early formula gives a resistance too large for observed facts; and he is doubtless correct, for our train speeds and Indicated Horse Power from indicator cards show that $P = 0.005\ V^2$ gives too high velocity resistance.

From the above equations the two following tables were computed. The first table gives the resistance due to train velocity which taxes the company through fuel and engine supplies. The second table is that portion of velocity resistance which increases the demand upon the locomotive and may threaten to limit the capacity of the locomotive.

TABLE II.—Resistance Offered by Still Air to the Progress of a Train Consisting of a Locomotive, Tender and Cars.

Speed in Miles per Hour	LENGTH OF TRAIN, INCLUDING LOCOMOTIVE AND TENDER.																	
	100 Feet		200 Feet		300 Feet		400 Feet		600 Feet		800 Feet		1,000 Feet		1,500 Feet		2,000 Feet	
	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power
10	13	0.4	16	0.4	19	0.5	22	0.6	28	0.8	34	0.9	40	1.1	55	1.5	70	1.9
20	54	2.9	66	3.5	78	4.1	90	4.8	114	6.0	138	7.3	162	8.6	222	12.	282	15.
30	121	9.7	148	12.	175	14.	202	16.	256	21.	310	25.	364	29.	499	40.	634	51.
40	215	23.	263	28.	311	33.	359	38.	455	49.	551	59.	647	69.	887	95.	1130	120.
50	335	45.	410	55.	485	56.	560	76.	719	95.	860	115.	1010	135.	1390	185.	1760	235.
60	483	77.	591	95.	699	112.	807	129.	1020	164.	1240	198.	1460	233.	2000	319.	2540	406.
70	657	123.	804	150.	951	177.	1100	205.	1390	260.	1690	314.	1980	368.	2720	507.	3450	646.
80	858	183.	1050	224.	1240	265.	1430	306.	1820	388.	2200	470.	2590	552.	3550	756.	4510	961.
90	1090	261.	1330	319.	1570	377.	1820	436.	2300	552.	2790	669.	3270	786.	4490	1080.	5700	1370.
100	1340	358.	1640	438.	1940	518.	2240	598.	2840	758.	3440	918.	4040	1080.	5540	1480.	7040	1880.

TABLE III.—Resistance Offered by Still Air to the Progress of that Portion of a Train which Follows a Locomotive Tender.

Speed in Miles per Hour	LENGTH OF TRAIN, EXCLUDING LOCOMOTIVE AND TENDER.																	
	100 Feet		200 Feet		300 Feet		400 Feet		600 Feet		800 Feet		1,000 Feet		1,500 Feet		2,000 Feet	
	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power	Tractive Force	Horse Power
10	4.6	0.1	7.6	0.20	11	0.3	14	0.4	20	0.5	26	0.7	32	0.8	47	1.2	62	1.6
20	18.	1.	30.	1.6	42	2.3	54	2.9	78	4.2	102	5.5	126	6.7	186	9.9	246	13.
30	41.	3.3	68	5.5	95	7.6	122	9.8	176	14.	230	18.	284	23.	419	34.	554	44.
40	73.	7.8	121.	13.	169	18.	217	23.	313	33.	409	44.	505	54.	745	79.	985	105.
50	115.	15.	190.	25.	265	35.	340	45.	490	65.	640	85.	790	105.	1170	155.	1540	205.
60	165.	26.	273.	44.	381	61.	489	78.	705	113.	921	147.	1140	182.	1680	268.	2220	355.
70	225.	42.	372.	69.	519	97.	666	124.	960	179.	1250	234.	1550	289.	2280	426.	3020	563.
80	294.	63.	486.	104.	678	145.	870	186.	1250	268.	1640	349.	2020	431.	2980	636.	3940	841.
90	372.	89.	615.	148.	858	206.	1100	264.	1590	380.	2070	497.	2560	615.	3770	906.	4990	1200.
100	450.	122.	759.	202.	1060	282.	1360	362.	1960	522.	2560	682.	3160	842.	4660	1240.	6160	1640.

We have seen that only in Goss's experiments have we been shown the first three resistances separately; viz.: Head Resistance, Intermediate Resistance and Trailing Resistance. Of the fourth, Oscillation Resistance, we can only say here that laboratory experiments do not show this, and that observations upon trains show the oscillation and the air resistances, as we have seen them to be, all in one measured or computed quantity. We must not forget that at speeds of say 80 miles per hour our present engines run with surprising steadiness on our best tracks; and it now seems that oscillating resistances are not large for our fastest trains. Of course, when a Mogul or Consolidation engine is speeded far beyond its designed rate with a train of ordinary freight cars, oscillation resistances are presumably large.

The general equation is for a locomotive and any train, either freight or passenger: $R = (0.105 + 0.010 N) V^2$, when R equals Resistance in lbs. total for train, N equals number of cars. A coach counts as two cars. Since this equation was not obtained from full size cars moving through the open air, but by models 1-32 the size of a box car placed inside an airtight conduit about six times the cross section of the models, through which air was blown, the equation is not as reliable as one made with cars in the open air. Nevertheless, it is valuable, and should be gratefully accepted. The experiments show that each intermediate car of a freight train offers 1-10 as much resistance as the front end of the train and that the last car of a freight train offers 2½ times as much resistance as any intermediate car. This is a suction resistance, and one but recently recognized.

The intermediate car resistances to head wind and the suction resistances determined are unique and instructive. It would be interesting to know how form of ends of cars and how vestibules of cars effect the resistance. Each added car, at least without vestibules, adds no doubt actual head resistance, as well as side frictional resistance. The formula allows us to predict this, at least.

Goss's experiments indicate that wind resistance on our western plains is a most serious resistance to all trains. Passenger trains are compelled to fall behind schedule time, and freight trains have to "set out" cars. A consideration in detail of wind resistance or impulse of trains is not within the province of the locating engineer, but of the operating department. It is best to say, perhaps, that wind resistances per sq. ft. at different velocities in miles per hour are given in most hand books. From this the head pressure of the front of the train is readily found. For the side resistance, we must take the friction of the angle. Unwin has given a formula for this.

The question of velocity resistance of trains is a vexed one. More experiments are needed. The experiments should be with actual trains of known grades and curvature or on straight, level track, and with cars of known sizes. The drop test would seem admissible. Small models, or models swinging around an axis in a

room, or even in a conduit, are not safely similar to trains in service. The old formula, $P = 0.005 V^2$, was probably for a windmill arm, a thin part of a stationary body, and was gotten from observations on winds slower than present express trains. To assume that a formula so deduced is applicable to velocity resistance of present trains is most daring. It seems now probable that it gives too large a result. Prof. Goss proposes to reduce it 50%. Or, shall we agree that it varies with the first power of the velocity, and use Crosby's formula, $P = 0.131 V$? Startling as this suggestion seems it gives results not far from observed facts.

Just after Mr. Crosby's experiments and Mr. Sinclair's observations, the late Mr. Wellington was of the opinion that these facts, taken in connection with what was before known, warranted a belief that the proper formula was $P = 0.24 V + 2$. (See Engineering News, June 9, 1892.) This was written but a short time prior to Mr. Wellington's death. The formula is intermediate in its value when compared with the range of values of other authorities.

We must conclude, therefore: (1) That the formula for velocity resistance, $P = 0.005 V^2$, is not entirely applicable to train resistance at present speeds, and gives the train resistance, due to velocity, too large;

(2) That the formula $P = 0.131 V$ is not improbable when judged by its results, but needs verification on full-sized cars in actual service or analogous conditions;

(3) That the formula $P = 0.0025 V^2$ is more nearly correct than $P = 0.005 V^2$, but needs additional proof under conditions more similar to practice to train service:

(4) That $P = 0.24 V + 2$ represents a conservative assumption for an expression for velocity resistance of present trains.

After presenting the present status of this question so that each one may judge for himself, we will use this last equation for velocity resistance.[1]

STARTING RESISTANCES.

The starting resistances of a train are all those resistances due to getting a train under motion. We shall consider the resistances which arise up to the time the train attains a speed of ten miles per hour. In railroad operation a train at ten miles per hour is considered to have sufficient headway to take care of itself in meeting bad track, small sags, etc. It is considered that the train having that speed is in a normal condition to combat any resistance. Moreover, the rolling and journal friction of a freight car is at its minimum at about ten miles per hour.[2]

[1] See Proceedings American Railway Master Mechanics' Asso. for 1897, page 219.

[2] Ec. Theory Ry. Location, p. 923.

The present means for overcoming starting resistances are three: (1) "Sanding the rail" for the driving wheels; (2) "taking the slack of the couplings;" (3) using steam non-expansively. Sanding the track increases the coefficient of friction of the driving wheel tires on the rails, making it about 0.33 or 0.35, whereas it is 0.25 without sand. By the use of sand the tractive power of a locomotive becomes one-third the weight on the drivers instead of one-fourth, as it is on an unsanded rail. This is an enormous increase in pulling capacity. It is not readily available for the first few feet without turning on the sand just before stopping. Sanding should be kept for such emergencies as a bad condition of rail or unusual load, and not be regularly relied upon for every day use.

By "taking the slack" of a train is meant availing ourselves of all the slack in the links and pins, or couplers of whatever sort, and also of all practicable compressibility of springs of the draw bars. A freight train does this by "setting up" the brake of the caboose, releasing all other brakes, backing the engine until the entire train commences to go backward, then starting the engine forward. The engine starts the forward car of the train while all the rest of the train is standing still. The initial resistances of a car being much greater than at any subsequent period, the aid to the engine by commencing to start but one car at a time is considerable. By the time the slack is nearly out and the last cars and caboose are about to start the engine and forward cars have attained sufficient velocity (though it be small in miles per hour) to largely reduce the tractive power required to move the forward portion of the train. In other words, "taking the slack" is in effect starting the train one car at a time, or adding to the train but one car at a time. Taking the slack is less used than formerly, for the present couplers have little slack.

By using steam non-expansively is meant the admission of steam from the boiler to the cylinder for the full length of stroke instead of "cutting off" the admission at part stroke so as to use the steam expansively for the remainder of that stroke. While running, the steam is "cut off" at about half-stroke and allowed to expand in the cylinder for the remainder of that stroke. This is the economical way of using steam, and while doing so the "lever," sometimes called "reversing lever," in the cab of the locomotive stands nearly vertical. In order to gain power, even at the expense of economy, the lever is thrown down from the vertical and set in the notch in the corner of the arc, "throwing her over in the corner," and the steam is admitted throughout the full stroke until the train gets under headway.

In recent years traction increasers have been used to aid passenger engines in starting trains. This consists in temporarily taking a part of the weight that rests on the front truck and putting it on the driving wheels by means of an auxiliary cylinder. It is unsafe to do this save at low speeds. It is not now in general use.

We shall now consider the nature and amount of each of the resistances which, taken together, comprise starting resistances.

First. The velocity resistance which forms a part of the starting resistance is the resistance due to the atmosphere as we start a train from a condition of rest and by uniform acceleration give it a speed of ten miles an hour. The resistance due to the train passing through the air is assumed to be the same as the pressure of the air in like motion upon a car end standing still. In other words, it is the average pressure of a wind at the average speed between 0 miles and 10 miles per hour, on the ordinary car end. This average wind of five miles per hour exerts a pressure of a little less than $\frac{1}{8}$ lb. per sq. ft. A car end has about 75 to 90 sq. ft. of area. A locomotive causes somewhat less resistance because better shaped to penetrate air, and therefore offers less real resistance to wind meeting it. Assume 80 sq. ft. as a fair average end area for a train to offer to the wind. The unit pressure per sq. ft. at the average speed of 5 miles per hour is $\frac{1}{8}$ lb. per sq. ft. We have 80 sq. ft. $\times \frac{1}{8}$ lbs. $=$ 10 lbs. pressure to be overcome by traction. This 10 lbs. added demand on the locomotive is insignificant. For speeds of less than ten miles per hour the resistance due to oscillation is probably so small we may safely disregard it. It is probable that at eight miles an hour, for example, the oscillation has a greater retarding effect than the air resistance. The writer knows of no experiments which throw light on this subject. The "wandering" of an engine on tangents and the "swaying" of cars are primarily caused by a too wide gauge, aided formerly by too much "coning" of wheels. The latter has been abandoned in so far as detrimental. The former is not used so indiscriminately as formerly, while heavier rails hold the gauge better.

Second. We need only say that the ordinary journal friction on straight level track applies in starting resistance. It is best to consider this normal resistance here as a part of the starting resistance, so as to enable us to provide for total starting resistance. This normal train resistance or rolling friction of about 7 lbs. per ton is added to the other resistances a train has at starting.

Third. Frictional resistance due to the low speed at starting is the most important part of starting resistance. We are not speaking of acceleration or inertia. We are not speaking of friction of repose. We speak of that large increase over the 7 lbs. per ton normal rolling friction which is caused by very low speeds as a train is getting started. The laws of friction have been worse than misunderstood. They have been thought to be too simple. Without discussing the general question of the laws of friction, it is now conceded that just as a train is starting there is a rolling friction in pounds per ton enormously in excess of normal rolling friction. This is the friction due to low velocity—the friction of slowness, if we may coin a phrase.

Friction and lubricants are inseparable in railroading. The question of friction at low speeds is closely related to lubrication. It is well known that a car that has been standing still for a long time requires more power to move it than if the car has been standing a short time. It has been suggested that the effort required to start it varies directly as the time. This seems questionable. The nature of the lubricant must be considered. Heavy grease or thick oil would increase in resistance longer than lard or light oil. Suffice it to say that cars start harder when "cold" from standing for some time, due to the effect of time on the lubricant. Such variation in resistance to starting cannot be measured. It may be estimated or allowed for. Better journal boxes, especially if they had "pads" or some other arrangement for taking the oil from the bottom of the journal box and spreading it constantly on the under side of the journal, would be helpful and make the resistance measurable.

From experiments made by the late A. M. Wellington for the Lake Shore Railroad and from previous experiments of others it is concluded by Mr. Wellington that this resistance due to slow motion is from, 14 lbs. to 28 lbs. per ton. Mr. Wellington's conclusion from his own tests, made in what was certainly as similar to actual conditions of car service as possible, was that this resistance varied from 18 lbs. to 24 lbs. per ton for low speed. Since lubricants are improving constantly, and as we have no recent experiments to guide us, we must assume a lower resistance than the average observed some years ago. We shall assume that this friction as above is 20 lbs. per ton as a safe average. This amount is not only the friction due to slow speed, but is journal friction as well. Hence 20 lbs. less 7 lbs. = 13 lbs. as the resistance due to friction at low velocity due to starting trains, or the friction of slowness.

Fourth. Grade resistance, which often forms a part of a starting resistance, is the normal grade resistance, as previously given.

Fifth. Acceleration resistance, or that resistance to a velocity of ten miles an hour (in this case) which a train at rest will offer. It is the inertia of the train. The accelerating force necessary to give the speed of ten miles per hour is equaled by the accelerating force of gravity which will cause that speed. This is measured by the "velocity head" or vertical height through which a body must fall under the action of gravity to attain a speed of ten miles per hour. Referring to Table I we find this to be 3.34 ft. after deducting 6% from the tabular value for wheel inertia. To make allowance for accelerating resistance at a station having a level grade 2,000 ft. or 20 stations, for example, it would be necessary to drop the grade line to an elevation of 3.34 ft. at 2,000 ft. from the starting point of the train, thus giving a descendant gradient of $\frac{3.34}{2,000}$

= 0.167% to neutralize acceleration resistance. Conversely, whenever we stop a train we add 0.167% to the gradient by reason of the accelerating resistance we incur. This must be taken into account in locating stops on a line.

It should be borne in mind that this 2,000 ft. of assumed level grade is 2,000 ft. between centers of gravity of the train. To have 2,000 ft. of level grade for starting a train we must have a level grade of 2,000 ft. plus the length of train in feet. At each locality, by adding 3.34 ft. to the elevation of the grade line above the datum and computing the new gradient from that new elevation, the elevation of the track at the center of the train on the level grade, and the distance of the new gradient can be computed. This will be a gradient including profile gradient and acceleration gradient. Ordinarily, the acceleration gradient is about 0.02 ft. per station. This gives 1,670 ft. between centers on which the train attains a speed of ten miles an hour. This is 4 lbs. per ton added resistance for acceleration.

The starting resistance due to sinking of track is one of which we may now speak. A committee of the Road Masters' Association of America, appointed to study "How Best to Prevent Creeping Rails," reported in September, 1898. The committee in this report quote experiments made in the Hawthorne yard of the C., B. & Q. R. R. by James E. Howard, of the Watertown Arsenal The conditions were as follows:

It was an October test on well settled track laid with 66-lb. steel rail on 17 oak ties to a 30-ft. rail, spikes redriven prior to test, cinder ballast on hard unyielding clay, weight of engine 55 tons. The middle driver of a six-driver locomotive sank 0.02 ft. Gravel ballast showed ⅔ as much sinking as cinders. Now, the car wheels would no doubt sink somewhat less. Again, a heavier engine would have greater effect, and on a road with no ballast, or soft track, the sinking would be materially increased. Its effect is to place our train on a grade due to sinking which is constant when the train is in motion, but most effective when the train is starting. Let us consider that the sinking is nil at 20 ft. from the middle driver. The gradient increase due to sinking 0.02 ft. is then 0.10%. If we double this for a soft subgrade, and add 25% for heavier engine, we have 0.25% for the addition of grade due to sinking. This is probably not an excessive amount.

In conclusion, starting resistances consist of a velocity resistance which is made up of about 10 lbs. total air resistance for the entire train and a greater amount—probably 20 or 25 lbs. oscillation resistance for the entire train. These velocity resistances due to starting are so small they may be disregarded. A normal journal and rolling friction is 7 lbs. per ton on straight, level track. A journal and rolling friction, due to low speed of starting, is approximately 12 lbs. per ton. The usual resistance due to the grade at the locality of starting will be a minus resistance when the

gradient is minus, and is then virtually an accelerating and not a retarding force or a resistance. This is the power needed to acquire the velocity head of ten miles an hour. It adds 3.34 ft. to the elevation to be overcome and ordinarily adds about 0.10% to the gradient. The resistance due to the sinking of track adds 0.25% to the gradient. The resistance due to slow speed is the greatest starting resistance, and probably equals the total of resistances due to acceleration up to ten miles an hour, normal rolling friction and all other starting resistances combined. The starting resistance to be added to the normal grade and rolling friction are, therefore, not less than 14 lbs. per ton. This is equivalent to a gradient of 0.7%, a gradient too large to be neglected in locating the line. Better attention to starting resistances on the part of locating engineers would cause less maximum demand on the locomotive at stations or other stops. The maximum demand should be on long stretches of track between stops.

Summarizing, we have the starting resistances expressed in terms of a gradient as follows: Acceleration = 0.10%; sinking of track, say 0.25%; resistance at slow speeds = 0.35%. This makes a total of 0.7%; hence a stop adds 0.7% to the rate of ascending grade.

GRADE AND CURVE RESISTANCES.

In America the terms "grade" and "gradient" are used as synonymous.[1] The term "grade" is also used as applying to the completed grading—excavation and embankment. We must use technical terms as we find them, if we hope to be understood. By "grade" and "gradient" we mean the ratio of the vertical to the horizontal distance that exists between two given points on the track or the grade line. This horizontal distance may be the mile, and we then speak of the line as rising and falling so many feet to the mile. Thus a 66-ft. grade means 66 ft. rise in a mile. This is the usual motive power parlance. Civil engineers and track men consider the horizontal distance to be 100 ft.—one station—and speak of the grade in feet and decimals, thus a 1.3-ft. grade, or better still, 1.3% grade means a rise of 1.3 ft. vertical in 100 ft. horizontal. This is the best and logical expression for rate of grade.

The maximum grade, or "ruling grade," is the highest permissible rate of grade on any one operating division. Level grades are self-explanatory. Minor grades are those neither maximum nor level. The influence of a minor grade on traffic is clear. A maximum grade has a similar effect, but in addition it has, if long enough, another and more important effect: that of limiting the capacity of the engines of that operating division.

We have shown in Chapter IV how the several preliminaries

[1]It is unfortunate that these terms are used indiscriminately. It would perhaps be better if the word "gradient" were applied solely to the slope of the grade line in feet per "station," as is done in England. The "subgrade" is the surface of the grade beneath the ballast.

are related to each other in the field. Suppose that several preliminaries are run between two points, and each line is mapped on the same sheet and each line has its profile on another sheet; assume, for illustration, that the chief of party is not instructed as to what maximum gradient to use, and that the preliminaries are the full length of the road; what maximum gradient should he use? He should select that gradient which will give a cost of construction reasonable for that region and its traffic. Never to lay a 1% gradient on a 1.25% profile is a good general rule. A profile shows on its face what should be the maximum gradient when looked at in the light of the volume and class of traffic; you should meet the economic gradients of your competitor, present or future.

Suppose the first preliminary, as above, has a profile requiring a 1.25% gradient, but that the second preliminary, being in easier ground, demands a 1% gradient. If we assume the preliminaries to be the length of an operating division, say 125 miles, instead of the entire length of the road, the problem is identical. This is the simple case of the question of economic maximum gradient.

Railroads, for the sake of instruction in gradients, may be said to be of two kinds, vertical and horizontal. The former we call elevators; the resistance these offer to the movement of traffic is the friction (sliding) plus 100% of the load. The latter, or horizontal railroads, are those with straight, level tracks; the resistance these offer to the movement of traffic is the friction (rolling) plus 0% of the load (assuming no friction due to velocity).

A gradient expressed in per cent. shows the per cent. of the load that is added to the resistance. For example, a 1% gradient offers 1% of 2,000 lbs. = 20 lbs. per ton resistance to traffic; and a 1.25% gradient offers 1.25% of 2,000 lbs. = 25 lbs. per ton grade resistance to traffic. In general, the question whether you should use a 1% or a 1.25% gradient depends upon whether you have such traffic that lifting 25 lbs. per ton instead of 20 lbs. per ton will cost less than the interest on the increased cost of construction of the 1% gradient instead of the 1.25% gradient line. On this basis we are disregarding minor matters: therefore, the cost of operating one maximum gradient as compared with another maximum gradient varies directly as the rate of grade. This is the fundamental property of maximum gradients. Any gradient, whether maximum or minor, having a less total rise than the "velocity head" (say 25 ft.) of the "virtual profile" for a train, is an exception to this rule, as we shall see later in this chapter; such maximum grades partake of the nature of minor gradients.

An increase in the rate of maximum gradient causes at once a marked increase in the demands upon a locomotive. This increased demand on the locomotive may be met by either using heavier locomotives or more locomotives. As is perfectly fair in the problem, we will assume that we use more locomotives; this

means more daily trains and more train miles. As the cost of the train mile is the same practically, we then have increased the cost of train service to 25, from 20, or a 25% increase. Since the train expenses are 47% of the total expenses (see Wellington's "Economic Theory of Railway Location," Table 80), the use of a 1.25% gradient increases the total expenses 25% of 47% = $11\frac{3}{4}$%. This increase of $11\frac{3}{4}$% added to the earnings, must be offset against a lower cost of construction, for example, of the 1.25% maximum grade division. We have then $11\frac{3}{4}$% of the total earnings as a sum to offset against an added cost of construction at, say 5%, assuming 5% to be the rate at which the company can borrow money on bonds selling at par. We have assumed a simple case, disregarding refinements of result to illustrate how directly important is maximum grade resistance.

We have now considered maximum gradients where they are long enough to be limiting grades. It is never customary to use a maximum grade less than 1,000 ft. in length in laying grades on a profile; ordinarily, one of less than 2,000 ft. long is not limiting, because of the vis viva of the train, as we shall see later. Besides this consideration of limiting effect, a maximum grade is classed with a minor grade and gives train resistance through its rise and fall.

Rise and Fall.

Transportation finds two classes of resistance in grade resistances: (1) The limiting effect of maximum gradients, already treated; (2) the resistance due to rise and fall which arises from any gradient, whether maximum gradient or minor gradient. If on a profile we rise 40 ft. and then descend 50 ft. in passing over a hill, that hill causes $\frac{50 + 40}{2} = 45$ ft. of rise and fall in the line. If a hill causes us to rise 35 ft. and descend 35 ft. it is said to have $\frac{35 + 35}{2} = 35$ ft. rise and fall. This rise and fall of a line is found by tracing through, on the profile, the actual rise and fall of each summit or depression and adding these amounts together. It follows that the total rise and fall of a line will be the difference in elevation of the extremities of that line plus the unnecessary summits and unnecessary "drops." If ground is found to support a grade line all the way so that it can be either climbing from the low end or running level all the way, the rise and fall is merely the difference in elevations of the terminals of the lines. This is the ideal preliminary, so far as rise and fall are concerned.

If, however, we add from the profile the rise and fall of each summit or depression as there shown and consider the sum of these amounts of rise and fall to be the rise and fall of that preliminary line, we shall be in error. Suppose, instead of adding the rise and

fall of each summit we add the rise and fall of each depression between those summits. It is clear that the total rise and fall will be the same by either method. But if a depression shows 35 ft. drop in grade line toward it, and 50 ft. of climb out of it, the rise and fall to be overcome by the engine is not 85 ft., because the engine and train in starting from rest at the summit back of the depression and running into the depression, even without steam, will gain enough headway in running down 35 ft. in grade to carry the train part way up the 50 ft. climb before the train stops, or is obliged to use steam. The summit the train would climb up, because of headway, must be deducted from 50 ft. to give the rise and fall. The energy acquired by the train in running down this 35 ft. descent is called kinetic energy, or *vis viva*. It is computed by the laws of falling bodies, but its amount in foot-pounds is not essential to our problem. That the train after running down a hill 35 ft. high will not rise to a height of 35 ft. ascent is plain, because it is retarded by friction, air resistances, etc. Suppose it will rise 20 ft., the engine must then exert force enough to haul the train the remaining 30 ft. of the hill to reach the 50 ft. summit. But suppose the train before it started into this depression was running at such a speed that it would readily climb a grade 30 ft. high by reason of its headway without using any steam. Then the train reaching the first summit at that speed would go down the 35 ft. grade, acquire headway sufficient to carry it up 20 ft. toward the 50-ft. summit, and would then rise the remaining 30 ft. by reason of its velocity. No added energy is needed by the engine in this supposed case; no added coal is used, and no added pull would be shown at any time on the head draw bar by a dynamometer. Therefore, this depression, operated under these conditions, offers no added obstacle in resistance to transportation. This is the principle of velocity-head applied to profiles, and is the foundation of the virtual profile, the construction of which is shown later.

The Virtual Profile.

The virtual profile is based upon the civil engineer's profile, made from measured horizontal and vertical distances on the ground or track; but this profile has then superimposed upon it the *vis viva* of trains just explained, and the velocity heads of trains at operating speeds on that part of the line. The profile of the line made by the civil engineer from his field notes is alone a dangerous document; the locomotive engineer or the motive power department must revise it by their experience and needs. Seeming mountains are often but mole hills. Whatever rise a locomotive engineer can climb, where he has a chance to "take a run at it," or better still, let his engine run for it with steam shut off, down a preceding hill, is a rise where money spent in reducing gradients is money wasted. Less often, but disastrously, what the profile shows as a harmless minor gradient at a station, limits the train load of some trains and removes the station from the line for other trains;

while the failure to ease off the upper end of a long maximum to help out the boiler on the over-cylindered engines, takes a car or two from every train going up that grade.

As one goes west over the Texas & Pacific Railway he climbs up a 1.25% gradient, unreduced over 3° curves through Carizo Pass in the Apache Mountain, to Allamore station at the summit. At the very top of that six-mile climb the writer revised the line and put in a 4°-curve, at the same time shortening the tangent to 50 ft. in length, which separated this 4° curve from the 3° curve which preceded it and turned in the opposite direction. The writer has since felt that that initial in railroad location should have ended his career as a locating engineer. The change lightened a cut; time was short for grading, and it was thought that a little shorter tangent and a little sharper curve were not serious; but this resistance was placed in the worst possible place on that one hundred miles of road.[1]

Many profiles ugly to look at are virtually level grades all the way, for the important trains of the line running with the heaviest traffic; while some very pretty profiles, from the civil engineer's standpoint, needlessly rob the investor of any hope of a dividend. The writer sincerely hopes that if this little volume accomplishes nothing else it will call the attention of all railroad engineers and most locating engineers to the fact that a profile of the ground along the line and a profile of the track do not furnish the material for judging between two preliminary routes, or give the value of a located line. The civil engineer's profile is the construction profile, not the operating profile. Construction should be a means, and operation must intervene before profit can ensue as an end. The tonnage, in direction and speed, must be taken into account; the stops for fuel, water, and traffic demand a grade all their own at each locality; and one hill is perhaps operated, in part or totally, by the next. The writer is reliably informed that Mr. John Hains on the D. & R. G. road a few years ago found by experiment that when trains could "make a run" they climbed 2,200 ft. of 1.25% rising grade by their own momentum.

One of two hills will often be found to offer no real obstacle to traffic either way, although it is a "bad bump" in a profile and looks ugly. The other hill, with its long, graceful grade lines giving delight to the eye of the locating engineer, may be a very bad place in the located line and just the place on which to spend money to improve the line. A located line should attempt to be such a line as will make the demand on the locomotive constant throughout its length; and the tonnage rating of that locomotive is the maximum tonnage for that locomotive for each foot of the line.

The writer, when chief of construction for a company building

[1]Major B. S. Wathen, now Chief Engineer of the T. & P. Ry., recently told the writer that the upper end of the Carizo hill reduced the train load two cars for the division.

railroads for the Chilean Government, had occasion to ride on the engine of a mixed train climbing the mountains from Coquimbo. It was a steep climb, with a succession of compound and reverse curves of "mule shoes," where the proverbial biscuit could be "tossed by the fireman to the rear brakeman." We stopped at stations, found level grades and occasional depressions in the grade line; we started and attained a good speed from each station, and then the engineer placed his lever in a certain notch, opening the throttle each time to the same extent, and the fireman kept close watch on the steam gage.

"Don't you ever shut her off or use your air," the engineer was asked.

"No, we can just about stay on the rails in the hollows," he replied.

"Don't you need to take a run at any of these hills?" the engineer was again asked.

"No," he replied, "when she pulls out of a station and strikes her gait, the train pulls just the same all the way to the next stop."

If that locomotive engineer was correct in his statements, that very difficult line is properly located. To the query as to who located the road the reply that "Some Englishman, name something like Duncan, I guess—died here," seems hardly sufficient renown for good work in by-places. This unknown Englishman made the demand on the locomotive a constant quantity; and that is the best monument for a locating engineer.

The highest speed at which a certain train can safely be run has a bearing upon the profile which is economical for that train. The faster a train can safely run, the greater the undulations of grade it can pass over without using steam, or with using only the steam pressure required on level grade. As a rule, the profile of a line, except near stations, must be adjusted to the economical running of freight trains.

Breaks in grades must not be too great nor the vertical curves connecting them too short or trains will break in two at them. It is essential that trains be always "stretched out." Young engineers make the mistake of using too long level gradients and too smooth a profile grade line in average country. They seek appearance. Old engineers chop profile grade line too much in average country. They seek to save cost of construction at the cost of operation. While the virtual profile is a valuable auxiliary to location it is more useful to re-location of a road which has been operated for some years. The location on the profile of the points where stops are made is of vital moment and so changes the virtual profile as to make it unrecognizable. It has shown us that good water from a tank in a sag at a lonely creek site was dearer than poor water at the town on the top of the hill beyond. Our villages should be on the hills for the benefit of the railroad interests. On a new road in an un-

settled country the towns, water stations and grade crossings of other roads should be chosen by the virtual profile.

To illustrate the use of a virtual profile we shall take two examples, referring to Plate 5 which shows the profile between Colorado River and Colorado—Brazos divide, on the T. & P. Ry. The profile grade elevations are shown below the ground line. The virtual grade elevations are shown above the virtual profile grade line. The left hand of the plate is to the west.

Example A. Assume that an eastbound train reaches Sta. 10,030 with a speed of 26 miles an hour and goes on east without stopping and runs to Sta. 9,827 using just enough steam to reach that point without any headway. Then the fact that the train took a "run for the hill" helped the engine as though the grade was flatter than the profile grade line of 1 ft. per 100 ft. We find from

TABLE I.—Velocity Heads.*

Condensed from Wellington's "Economic Theory of Railway Location," page 335.

Miles per hr. (V)	Head in ft. (H)	Miles per hr. (V)	Head in ft. (H)	Miles per hr. (V)	Head in ft. (H)	Miles per hr. (V)	Head in ft. (H)
1	0.04	11	4.30	21	15.67	31	34.12
2	0.14	12	5.11	22	17.19	32	36.35
3	0.32	13	6.00	23	18.79	33	38.66
4	0.57	14	6.96	24	20.46	34	41.04
5	0.89	15	7.99	25	22.20	35	43.49
6	1.28	16	9.09	26	24.00	40	56.80
7	1.74	17	10.26	27	25.88	45	71.89
8	2.27	18	11.50	28	27.83	50	88.75
9	2.88	19	12.82	29	29.86	55	117.38
10	3.55	20	14.20	30	31.95	60	127.80

*$H = v^2$ (in ft. per sec.) $= \dfrac{1.467^2 V^2}{64.32}$ and adding 6.14% for rotative wheel energy we have $H = 0.0355 V^2$.

Table I that at a speed of 26 miles per hour a train has a velocity head of 24 ft. At Sta. 10,030 plat this 24 ft. on the profile, counting upward from the ground elevation of 2,124.8 to an elevation of 2,124.8 + 24.0 = 2,148.8, and from this point on the profile draw a straight line to the ground elevation at Sta. 9,827; since the train is assumed to have no speed there the virtual profile coincides with the track profile. Now, this rate of virtual gradient from Sta. 10,030 El. 2,148.8, to Sta. 9,827 El. 2,297, is by computation 0.73 ft. per 100 ft. The demand on the engine is therefore as on a 0.73% gradient, and not as on a 1% gradient as the profile indicates.

Example B. Assume that a westbound train reaches Sta. 9,-700, running 28 miles an hour, and wishes to use as little steam as possible and pass Sta. 9,760 at a speed of 10 miles an hour—a usual minimum speed for safe operation. What virtual gradient has this engine here to overcome? In Table I, the velocity head of a train

running 28 miles an hour is 27.83 ft.; add this to the grade elevation of the track at Sta. 9,700 and we have 2,254.64 + 27.83 = 2,282.47 = El. virtual profile for this train. The table gives 3.55 ft. as the velocity head at 10 miles an hour; hence 2,290.72 + 3.55 = 2,295.00 = El. virtual profile at Sta. 9,760 for this train. By computation, the virtual gradient for this train under these working conditions, is 0.21%, and not 0.82% as appears.

It is instructive to note that if the train passes Sta. 9,700 going at 28 miles an hour, and with a certain steam pressure, the throttle being in a position to keep the train going on a level track, and these two conditions be not changed, then the train will stop between Stas. 9,744 and 9,745; since the *vis viva* has there been overcome by the adverse gradient, and the steam pressure was only sufficient to haul the train on the level grade at and back of Sta. 9,700.

In taking advantage of the "velocity head" of the train, we must not consume all of that velocity head in climbing a hill. Temporary irregularities of track near the summit may "stall" the engine. Of course it would consume too much time to allow the train to come to a theoretical stop at a summit, and it is usually impracticable in railroad operation. It is the usual practice to consider that ten miles an hour shall be the minimum safe working speed for trains.

The velocity head for ten miles an hour is 3.55 ft., therefore the grade line of a virtual profile should always be, at least, 3.55 ft. above the track profile. This lessens the amount of benefit to be had from velocity head in operating a line. By using Table I, we find that for a greatest depth or say 25 ft. and a maximum speed of approach of 10 miles per hour, the maximum speed in the bottom of the sag is 28.3 miles an hour. This last rate of speed is not excessive to-day for freight train on fair track, and the track should always be best in the sags. We shall, therefore, assume that for freight trains 25 ft. can safely be taken out of the sags by velocity head of train; that is, a sag of 25 ft. or less has no grade resistance which increases the demand upon the engine; or, on a 1% maximum grade not over 25 stations long, we cannot afford to spend money to lighten grades because of the demand on the locomotive. This fact is revolutionary to a profile. It shows that, within this limit, an undulating grade line ("chopped grades," so called) has no effect upon the demand on the locomotive; and since there is no effect on the demand there can be no effect on the capacity of the locomotive. The evil effects of undulating grades not exceeding 25 ft. rise and fall must then be looked for in minor expenses of maintenance of rolling stock and track; and due appreciation of this fact by locating and chief engineers saves much money to be applied economically elsewhere.

The practical effects of the foregoing fact upon our problem are: (1) Disregard all sags of 25 ft. or less for freight trains and still greater ones for passenger trains; (2) For sags of more than

25 ft. a virtual grade line and virtual gradient must be used for computing train resistances due to grades; (3) At points where trains stop, such as stations, grade crossings of other lines, water tanks and coal chutes, a virtual grade line and virtual gradient must be used to determine the train resistance. This gradient increases a rising grade and decreases a descending grade of the profile from that stop forward to where the train first attains its desired running speed of, say, 25 miles per hour. These three rules materially modify the amount of rise and fall to be charged against a preliminary whose merits we are weighing. By their observance we may disregard sags of 25 ft. or less, avoid much grading; they lead us to lay a new grade line at all long hills, and tend to increase largely the importance of these hills in railroad location; and they cause the question of acceleration of trains as a demand on the locomotive to be taken into account in railroad location and design.

That undulating grades, within narrow limits (short hills), are not very objectionable between stations is not news to old locating engineers. They frighten a younger man and displease a director who has not operated a line; but a locomotive engineer has never objected to them. The latter "rolls down" one grade and "takes a run at the next," and it gives time to clean fires and attend to his engine while the demand on the engine is little or nothing.

That long, ascending grades are the "bête noir" of the locomotive fireman all know. The demand on the locomotive should be made to lessen, if possible, as we approach the top of a long hill; for an engine cannot exert a pull equal to its maximum performance on the upper portion of a hill several miles long. It is safe to say that engines are usually over cylindered, and can start or pull for a short time more than they can sustain later; the power of the locomotive finally, falls to the boiler capacity, or, more likely, to the grate capacity. The locating engineer needs to take counsel of the locomotive engineer, and ease off grades at the top of long hills if at all possible, remembering that increasing the gradient at the bottom of a hill (last 25 ft. of height) is allowable. For example, curvature near summits should be avoided, or, when used, equated for more liberally at the top of a long hill than at the bottom.

A railroad must be so located that grades can be reduced at station sites. Locating a road with no regard to traffic points is clearly very unwise; and many good towns contribute much less traffic to a certain line than the town would do, because the line was needlessly so located that trains cannot be stopped at the nearest point on the line to that town. The depot may have had to be placed out some distance on the line in order to be able to start trains out of the depot. It is self-evident, therefore, that a locating engineer needs to have had some experience on maintenance of way, or better still, in the transportation department.

A proper regard for virtual profile would have avoided much

expenditure now being made by our best railroad lines for reconstruction.

All reconstruction and relocation are not, however, made necessary by bad original location. When traffic changes, in volume, place of origin, or direction (as it is certain to do in some localities) a good original location may become a very poor final one.

Before passing from the subject of virtual profiles it may be well to state where the virtual grade line should be platted above the profile of the ground on the usual profile roll. There is clearly no necessity for platting it always; and it may be stated generally that the virtual grade line need never be platted in the following places:

(1) Between stations on level, or nearly level gradients, or where the sags are less than the velocity head of the ruling trains (assumed here as 25 ft.), or where the hill is less than that velocity head and there is a chance to "take a run" for that hill; (2) At stations or other stops on level grades, or where the grades allow room for train acceleration, or on the up hill side of a station, or other stop.

On the contrary, it will usually be profitable to plat the virtual grade line at the following places:

(1) Between stations where quite long hills exist, especially if the maximum profile grade occurs for some length on that hill;[1] (2) On seemingly undulating grades showing sags or hills exceeding the velocity-heads (3) At any station, or other stop of trains.

Vertical Curves.

Vertical curves are used to lessen the shocks to the train when passing over changes in the rate of grade. When the gradient changes there is an angle in the grade line of the profile; and when this angle is sufficient to endanger the car couplings and cause a train in passing over that change in gradient to break in two, it is necessary to connect these two grade lines by a vertical curve. This is sometimes called "rounding off the grades." Instead of using vertical curves, it was once the practice to use 200 ft. of level grade between considerable changes in grade; in which case the roadmaster had a better chance to put in a vertical curve; and on such roads the locating engineer left a good deal for the roadmaster to do before trains could be run with any safety or speed. As soon as vertical curves came into use a parabolic instead of a circular curve was recommended, for the manifest reason that the change in direction is easier on parabolic curves. The authors of handbooks, Henck and others, gave such curves twenty years ago; but many

[1]It is the practice on the Great Northern Railway to deduct nothing for velocity-head when hills much exceed 100 ft. in height. The reason assigned is that the engine while running at its maximum allowable speed at the bottom of the hill loses tractive power. The speed at the bottom of the hill is uneconomical there.

engineers then on construction were incapable of using even these quite simple tables. Locating engineers continued to "break on 200 ft. of level grade" and the roadmaster did the rest necessary for the superintendent. Vertical curves were delayed in their general introduction in the West by Construction Companies and Improvement Companies,—those blights upon railroads—instituted for the benefit of the larger owners at the expense of the smaller owners. A vertical curve increases the embankment if used at a sag or bottom of an up-grade, and it increases the excavation if used at a summit, or top of an up-grade. As these localities are precisely where the vertical curve is most needed, these curves were avoided by construction companies to save grading. As most of these companies had their own engineers, the vertical curves were left out.

The nature of the car coupling has to do with the length of the vertical curve needed. The angle of repose of the car is the greatest rate of change of gradient at which it will rest on the rails without starting to move. This angle of car repose limits the change in gradient per station. Since the greater the speed the greater becomes the angle of repose, it follows that the vertical curves need to be longest for the slower trains. The old link-and-pin coupling needed longer vertical curves than the present automatic couplers. A vertical curve demanded ten years ago is not needed now; and the rule of Mr. Wellington, that "Vertical curves in sags should be 400 ft. long for each tenth in change of rate in grade," is now excessive in length of curve on account of changed conditions. In changing from a 0.0% to a 1.25% gradient the length of vertical curve would be $\dfrac{400 \times (1.25 - 0.0)}{0.10} = 5,000$ ft.

The ideal condition is attained when "the rate of the grade on which the head of the train stands must in no case exceed that on which the rear of the train stands by more than the grade of repose of the last car." This ideal condition can be largely discounted in practice, and later researches in velocity resistances tend to shorten the desirable length of vertical curves. To use vertical curves is important; that we use them as short as possible without breaking trains in two is wise; that the length of these vertical curves bears a reasonable proportion to the magnitude of the change in direction in grade lines of the profile is good common sense. Each engineer may, with safety, follow any logical plan having the desired objects in view. The writer's practice is as follows:

The journal and rolling friction of a car on a straight, level track is 7 lbs. per ton. Since grade resistance per ton is that part of a ton which the grade per 100′ is of 100, then conversely $\dfrac{7}{2,000} \div 100 = 0.35 =$ the grade at which grade acceleration will commence to overcome journal and rolling friction. Therefore,

a grade greater than 0.35 ft. per station of 100 ft. will cause a car to "run up" on its forward coupling. This is undesirable. To be on the safe side, instead of 0.35 ft. let us use 0.3 ft. as the maximum change in rate of grade per station on a vertical curve. In practice, we count from the vertex each way for the end of the curve. The curve is therefore an even number of stations long. Changing from +0.0 to +1.25 ft. we will have $\frac{1.25 - 0.00}{0.3} = 4$, a curve 400 ft. long—200 ft. each side the vertex. If we change from a + 1.00 to — 1.00 we have $\frac{1.00 + 1.00}{0.3} = 7$ Stas. nearly. Use here the even number above, or a vertical curve 8 stations long. Where grades change but 0.30 ft. in direction no vertical curve is needed. Where grades change but 0.60 ft. "round off" the vertex station. Where grades change from 0.60 ft. to 1.00 ft. in direction, round off the vertex station considerably, and the stations adjacent one-fourth as much. These small changes are readily made without any vertical curve computation. In practice, vertical curve is not computed for minor gradients. For maximum gradients, any of the field books give tables.

CURVE RESISTANCE.

Of late years, curvature has been "equated for"[1] on location profiles. This should, of course, be done on preliminary lines also. It is frequently done on preliminaries by a vertical offset in the grade elevation sufficient to allow for equating all the curvature for some distance. A locating engineer must estimate his curvature for a certain climb or drop on reconnaissance so as to enable him to allow for it in his hand level work. Equating for curvature is so essential to good practice that we have a right to assume that in the future it will be the invariable rule. We shall therefore consider in studying curve resistance that it is to be equated into rise and fall. To determine the actual resistance offered to traffic by a certain curve is not a simple question in mechanics. It is necessary to make broad assumptions. How a four wheel truck, pivoted on its center and having its wheels solidly fixed on the axles, will travel on a curve is not always easy to predict. Which wheels slip along the top of rail? Which wheels impinge against the side of the head of the rail? Will a six-wheel truck act similarly to a four-wheel truck? What relative effect has the amount of coning of the wheels upon curve resistances?

The late A. M. Wellington found by experiment that the wheel

[1]The making of an allowance for the frictional resistance on curves due to the rubbing of wheel flanges on the rails, and the slipping of the wheels is "equating for curvature."

on the outer rail of the leading pair of wheels on a four-wheel truck always followed the inner flange of the outer rail and caused all of the flange friction; and that the axis of the trailing pair of wheels is radial to the curve when free to assume its own position. While it is not clearly capable of demonstration by data now known, it is probable that a four-wheel truck acts as follows: The outer wheel of the leading axle of the truck on a curve impinges by its flange against the inner side of the head of the outer rail (See Fig. 39), and produces all of the flange friction of the truck; this wheel does not slip longitudinally at all. The inner wheel of the leading axle slips longitudinally by an amount in 360°, equal to the circumference of a circle whose radius is the gage of the track. The outer wheel of the trailing axle slips along the outer rail an amount equal to that which the inner wheel of the inner axle slips on the inner rail. This wheel causes, therefore, all the wear on the top of the outer rail. The inner wheel of the trailing axle produces no slipping wear, and no flange friction normally. It causes on the inner rail the rolling friction as on a tangent. This distribution of the friction of the truck to the different wheels presupposes such spread of gage on the curve that the resistance is least, i. e. the trailing axle is radial to the curve and the truck pivots about the inner trailing wheel.

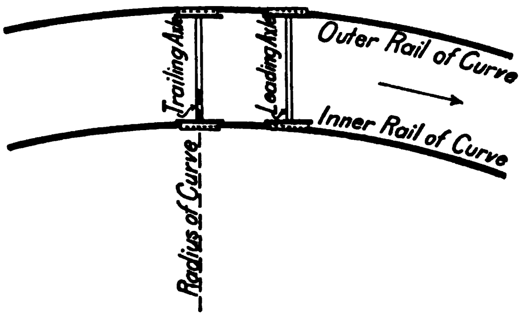


Fig. 39.

For trucks of six or more wheels, we are obliged to assume that the axles intermediate between the leading and trailing axles are non-resistant; except, that if the gage be too narrow, they may increase the flange friction, or even destroy the track or truck.

"Coning" car wheels consists in making the outer circumference of the wheel, exclusive of the flange, a conical surface instead of a cylindrical surface. Its object was so to increase the diameter of the rim of the wheel on the side nearest the flange that the wheel would not slip in passing around a curve. The wheels were supposed to run around curves with the flanges of the wheels close to the inner edge of the outer rails. It was a theoretical solution of slipping of wheels on curves, though it failed in part because not all pairs of wheels so traveled. It was found that wheels coned properly for curves caused the wheels to "wander" on tangents, i. e., follow one rail for a distance, then swerve over to the other rail. This oscillating was undesirable. Partial coning is now practiced.

Since the amount of slip for each 360° curvature is the circum-

ference of a circle whose radius is the gage, the sharpness of a curve has no effect on resistance due to slip.

$$\text{Slip}=2\pi r-2\pi(r-4.75)$$
$$\text{"}\ =2\pi r-2\pi r+2\pi\, 4.75$$
$$\text{"}\ =2\pi\times 4.75=\text{Arc of circle whose radius}=\text{gage.}$$

Having considered how curve resistances arise and of what they consist, what is the amount in percentage of load or in lbs. per ton? We have seen that the resistances are of two kinds; flange friction, and sliding friction. We have seen that sliding friction is independent of the degree of curvature, i. e., that curve resistance due to slipping is no more per degree of curvature on a sharp than on a flatter curve. Since we consider a four-wheel truck to pivot on the inner wheel of the trailing axle, the flange friction must all take place on the outer rail at the outer wheel of the leading axle. This presupposes a nice balance between the super-elevation of the outer rail and the speed of the train. Under this ideal condition we have for slipping resistance, the average slip for the four wheels multiplied by the coefficient of sliding friction; and as this coefficient is the same here as in the traction of a locomotive, we assume the same percentage, 25%. The determination of the slip for each wheel is capable of ready solution for any given truck. For a four-wheel truck, 5 ft. long, on a 1° curve, the average slip of a wheel is 0.073 ft.[1] The resistance of the truck due to curvature = 0.073 + 0.25 × 2,000 = 0.365 lbs., resistance per ton for the slipping due to curvature.

The resistance of curvature due to flange friction is similarly considered but not so readily computed. The surface of the rail in contact with the wheel flange varies for different rail sections and for different stages of wear of rails. The farther down the side of the head of the rail the flange is in contact with that railhead the greater the flange resistance. To compute the flange friction, we must first know the exact shape of the flange face and the rail head; and as the latter is never constant it is idle to so compute it. We can only know the flange friction by deducting from observed total curve resistance the resistance due to slipping. Experiments are needed better to determine curve resistance under varying conditions. Mr. Wellington gives some deductions from experiments by the drop test made on the Lake Shore Ry. There may be later tests. The conclusion there stated is that a 1° curve offers over 1 lb. per ton at 12 miles per hour, and ½ lb. per ton at 22 miles per hour. Earlier experiments than Mr. Wellington's show that for sharp curves the resistance is about 0.4 lbs. per ton per degree of curve. And from these two experiments, we have generally come to consider that one degree of curvature offers a total resistance due to curvature of 0.5 lbs. per ton.

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[1]Wellington's "Economic Theory of Railway Location." p. 286.

The proceedings of the American Railway Master Mechanics Association for 1897, page 219, gives curve resistance of cars as 0.5 to 0.7 lbs. per degree of curve and 1.40 lbs. for locomotives. It is concluded that the resistance is as the total number of degrees of curvature, irrespective of the degree of curve. It follows that rail wear on a curve is as the tonnage, and not as the degree of the curve. It must be said that the most recent practice in engine rating tends to the practice of considering ½ lb. per ton per degree of curvature as too small; and motive power men consider this figure insufficient.

EQUATING FOR CURVATURE.

In laying the grade line on the location profile, the rate of maximum gradient per station must be reduced by such an amount as necessary to compensate for resistance due to curvature.

The reduction in gradient formerly was 0.05 ft. per station (of 100 ft.) for each degree of curvature. If the maximum gradient was 1%, then a 10° curve would have to have a level grade. As this rate was established by trial of locomotives it varied on different roads. Shunk's formula for equating gradient for curvature was as follows:

$$\frac{(\text{Degree of curvature})^2 + 10\,(\text{Degree of curvature})}{500} = \text{reduction in}$$

gradient per 100 ft.

This gives an 18° curve as requiring a level grade line when the maximum grade is 1 ft. per 100 ft (1%). These two rules for finding the amount to be used in equating curvature probably represent the extremes. Mr. Wm. B. Morley, at the time of his death in 1881, the Chief Engineer of the Mexican Central R. R., was in his earlier life a prominent locating engineer. He has stated that in his work in and near Veta Pass, the gradients were not reduced on curves of 10°, or flatter. For the increase in sharpness of a curve beyond 10° the reduction was 0.05 ft. per 100 ft. for each degree of increase per station until at 33° curve there was a level grade. Locomotives stalled with their trains on the lower grades (flatter curves) first. A sliding scale of reduction was then used as follows:

For level to 0.7% ft. gradients use 0.06 ft. per Sta. per Deg. of curve.

For 0.7 ft. to 1.4% ft. gradients use 0.05 ft. per Sta. per Deg. of curve.

For 1.4 ft. to 2% ft. gradients use 0.04 ft. per Sta. per Deg. of curve.

When the line was equated for curvature according to this sliding scale, it was observed that engines stalled at no one point more than another.

The foregoing shows the wide divergence of opinion and practice. But it must be remembered that prior to these steps there

were many miles of railroad built where maximum or minor curvature was piled upon maximum gradient with no pretense of reduction. The amount of curvature, 5° and flatter, that exists in America on unreduced maximum gradients is enormous. Such is the history of choice of lines and of equating. The equating for curvature remains in use as it is based on observed fact.

ELEVATION OF OUTER RAIL.

The super-elevation of the outer rail on a curve cannot be right in amount for all trains, for velocities vary. Some roads elevate the outer rail on their curves nearly enough for the fastest passenger train. The Lehigh Valley R. R. did this some years ago on parts of the Wilkesbarre Mt., and the effect is that the trucks of slower trains, carrying the greater part of the tonnage, crowd close to the inner rail; the inner wheel of the trailing axle probably cutting away the outer side of the head of the inner rail; and the action of a four-wheel truck is entirely different from normal conditions. On the other hand, if the super-elevation of the outer rail be the economic amount, the average train acts normally; the faster trains have the normal effects merely emphasized, while the slower trains somewhat reverse the effects as outlined. What should be the proper elevation on a given part of a given road is really a question for the roadmaster or his immediate superior, if a track man, to decide.

The following has been the writer's practice. On maintenance of way, keep the top of the inner rail to the exact grade line of the track profile. Do not lower the inner rail. Start the elevation of the outer rail a distance back of the P. C., along the tangent, proportional to the super-elevation for the center of the curve and coincident with the easement curve, if such be had; continuing this super-elevation an equal distance beyond the P. T. on the tangent. Where easement or spiral curves are used, the super-elevation should begin and reach its maximum on the easement. Give such a super-elevation as will not endanger the derailing of any of the trains as they run over the curve. Try to adjust the super-elevation of the outer rail from the P. C. to the P. T., so as to get the greatest "expectation of life" to the track on the curve. On construction, depart from this practice in so far as is necessary to lower the inner rail and raise the outer rail one half the super-elevation desired. This is for convenience in computing quantity in cross section.

A curve in a sag must ordinarily have a super-elevation greater than a similar curve on the summit beyond that sag; because the average train runs faster in the sag than on the summit. There is much conflict of opinion and much discrepancy to-day in the matter of super-elevation. Ordinarily, most roads now use somewhat less than an inch super-elevation for each degree of curvature, but lessen this per degree on the sharper curves.

EASEMENT CURVES.

We have not mentioned the shock, and consequent resistance at entering and leaving a curve, though roadmasters have lessened this much. A locomotive tends to move tangentially; as it approaches a curve, it strikes the outer rail hard, and tends to thrust the beginning of the curved rail away from the P. C.; and as the engine leaves the curve with comparatively little effect on the rail the curves shorten. Trackmen correct this, and lessen the shock at the ends of the curve by going back on each tangent beyond the P. C. and P. T., and start the curve by throwing the track in, thus combating the engine tendency to throw that track out. Of course the roadmaster must make the original curve sharper somewhere in its length, or else throw it in for its entire length. Maintenance of way engineers put in easement, or spiral, or taper curves (the three terms are synonymous), making trigonometrically exact what the roadmaster can do by the eye. By an easement or spiral curve we mean one which starts from a tangent very easily and increases its sharpness by some law until it becomes as sharp as the degree required, say 6°. The usual circular curve is then run-in to a point where the other easement must commence and taper in degree of curvature from the 6° to a 0° at the P. T. In other words, for the 6° curve just cited, we use 300 ft., more or less, of track distance to change the direction of the locomotive instead of changing in no distance, or at the mathematical point which is our P. C.

It may safely be assumed that no experienced roadmaster or locomotive engineer needs to be persuaded that easement curves are desirable. Civil engineers are not so positive of their value.

If we grant that easements are desirable, it follows that they should be put in while locating the line. One road, using them largely, finds that running in easement curves increases the cost of location but 1%. This is not over $1 per mile of line and is insignificant in cost. There is considerable literature on this subject. Prof. C. L. Crandall has an admirable book on the spiral. Mr. Wm. H. Searles has also a good work and Henck treats of it, in late editions.

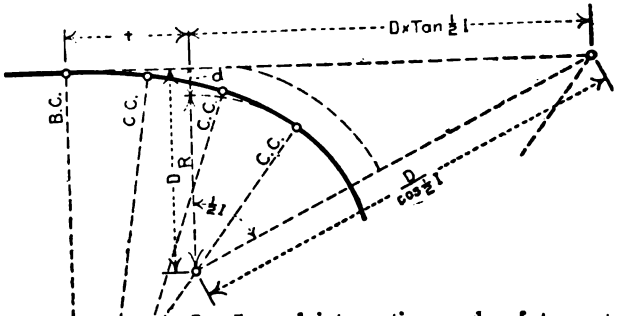
Easement curves are parabolas, or closely resemble them. In publications the cubic parabola is often used. Its equation

$$Y = \frac{X^3}{6 R x}$$

But in practice, a compound curve of equal chord lengths is most used. A chord of 30 ft. or 50 ft. is common. A road will use one to three different spiral curves, using the sharper and shorter where there is not room for the longer and easier one. The taper curves used by the Southern Pacific Railway are here shown.

These tables were made by Wm. Hood, Chief Engineer of the Southern Pacific Railroad, and have been in use for a long term of years (Fig. 40). Field computation is by these tables reduced to a

Fig. 40.—Taper Curves, So. Pac. Ry.
Showing "D," "d," "t," of Tapering-Curve Tables



Let I equal intersection angle of tangents to curve, then:—

1. Distance from middle of curve to intersection point equals D × ex. secant ½ I + d, or $\frac{D}{\cos. \frac{1}{2} I}$ —Radius of main curve.

2. Distance from B. C. to intersection point equals D × tangent ½ I + t.

3. In running these curves on the ground, it is best to fix the B. C., E. C. and C. C.'s of main curve from each other by the proper deflections and long chords, the other C. C.'s being put in by successive deflections and short chord measurements.

4. Should the main curve be other than one shown in the tables—for instance, a 6° 30′ curve, to be tapered per Table 2—run in the tapering curve to C. C. 6° 00′ (putting in this C. C. by tabular long chord and deflection), and then run in 15 feet of 6° to C. C. 6° 30′—in all cases taking some convenient length of chord for the last compounding of the tapering curve, which length shall have, as nearly as may be, the same relation to the tabular chord length as the main curve bears to the adjacent tabular curves. Get corrected values of D and t by multiplying cosine and sine of total curvature up to main curve by the difference of radii of main curve and of last branch of compound curve; subtract cosine product from D, and add sine product to t (as taken from the table for the last branch of the compound curve).

Table 2—TAPERING CURVES

Changing 1° 00′ to Each 30 Feet

Transit at	DEFLECTIONS TO									
	B. C. 1°	C. C. 2°	C. C. 3°	C. C. 4°	C. C. 5°	C. C. 6°	C. C. 7°	C. C. 8°	C. C. 9°	C.C.10
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
B.C. 1°	....	0 09	0 22½	0 42	1 07½	1 39	2 16½	3 00	3 49½	4 45
C.C. 2°	0 09	....	0 18	0 40½	1 09	1 48½	2 24	3 10½	4 03	5 01½
C.C. 3°	0 31½	0 18	....	0 27	0 58½	1 36	2 19½	3 09	4 04½	5 06
C.C. 4°	1 06	0 49½	0 27	....	0 36	1 16½	2 08	2 55½	3 54	4 58½
C.C. 5°	1 52½	1 33	1 07½	0 36	....	0 45	1 34½	2 30	3 31½	4 39
C.C. 6°	2 51	2 28½	2 00	1 25½	0 45	....	0 54	1 52½	2 57	4 07½
C.C. 7°	4 01½	3 36	3 04½	2 27	1 43½	0 54	....	1 03	2 10½	3 24
C.C. 8°	5 24	4 55½	4 21	3 40½	2 54	2 01½	1 03	....	1 12	2 28½
C.C. 9°	6 58½	6 27	5 49½	5 06	4 16½	3 21	2 19½	1 12	....	1 21
C.C.10°	8 45	8 10½	7 30	6 48½	5 51	4 52½	3 48	2 37½	1 21	....

FOR TABLE 2

Degree of Main Curve	"D"	"t"	Total Curvature in Tapering Curve at Each End of Main Curve	"d," = "D," less Radius of Main Curve	Long Chord from B. C. of Taper to C. C. of Main Curve
			° ′		
2°	2864.87	15.00	0 18	0.08	30.00
3°	1910.08	30.00	0 54	0.14	60.00
4°	1432.85	45.00	1 48	0.38	90.00
5°	1146.78	60.00	3 00	0.77	119.99
6°	956.40	74.99	4 30	1.36	149.96
7°	820.82	89.95	6 18	2.18	179.91
8°	719.62	104.90	8 24	3.28	209.81
9°	641.47	119.80	10 48	4.69	239.63
10°	579.59	134.66	13 30	6.45	269.35

RADII FOR 50 FEET CHORDS

Degree	Radius	Degree	Radius
° ′		° ′	
1 00..	5729.61	6 00	955.04
1 30.	3819.74	6 30	881.59
2 00.	2864.84	7 00	818.64
2 30..	2291.88	7 30	764.08
3 00..	1909.91	8 00	716.34
3 30..	1637.09	8 30	674.22
4 00.	1432.47	9 00	636.78
4 30..	1273.32	9 30	603.29
5 00..	1146.01	10 00	573.14
5 30.	1041.84	....	....

Fig. 40.—Taper Curves, So. Pac. Ry.—Continued.

Table 1
TAPERING CURVES
Changing 0° 80′ Each 80 Feet

Transit at	DEFLECTIONS TO B. C. 0° 80′	C. C. 1° 00′	C. C. 1° 80′	C. C. 2° 00′	C. C. 2° 80′	C. C. 8° 00′
° ′	° ′	° ′	° ′	° ′	° ′	° ′
B.C.0 80	....	0 04⅛	0 11⅛	0 21	0 88⅝	0 49⅛
C.C.1 00	0 04⅛	....	0 09	0 20⅝	0 84⅛	0 51⅝
C.C.1 30	0 15⅝	0 09	....	0 18⅛	0 29⅝	0 48
C.C.2 00	0 38	0 24⅝	0 13⅛	...	0 18	0 88⅛
C.C.2 80	0 56⅝	0 46⅛	0 83⅝	0 18	....	0 22⅛
C.C.8 00	1 25⅛	1 14⅝	1 00	0 42⅝	0 22⅛	....

Table 3
TAPERING CURVES
Changing 2° 80′ to Each 80 Feet

Transit at	DEFLECTIONS TO B. C. 2° 80′	C. C. 5° 00′	C. C. 7° 80′	C. C. 10°00′	C. C. 12°80′	C. C. 15°00′	C. C. 17°80′	C. C. 20°00′
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
B.C. 2 80	......	0 22⅛	0 56⅝	1 45	2 48⅝	4 07⅝	5 41	7 29⅛
C.C. 5 00	0 22⅛	......	0 45	1 41¼	2 52⅛	4 18⅝	6 00	7 56
C.C. 7 80	1 18⅝	0 45	......	1 07⅛	2 26⅝	4 00	5 48⅝	7 52⅛
C.C.10 00	2 45	2 03⅝	1 07½	....	1 80	8 11⅝	5 07⅝	7 18¾
C.C.12 80	4 41⅝	8 52⅛	2 48⅝	1 80	....	1 52⅝	8 56⅝	6 15
C.C.15 00	7 07⅝	6 11¼	5 00	8 88⅝	1 52⅛	...	2 15	4 41⅛
C.C.17 80	10 04	9 00	7 41⅝	6 07⅛	4 18⅝	2 15	....	2 87⅛
C.C.20 00	13 80⅛	12 19	10 52⅛	9 11⅛	7 15	5 08⅝	2 87⅝	....

Table 4
TAPERING CURVES
Changing 2° 80′ to Each 15 Feet

Transit at	DEFLECTIONS TO B.C. 2° 80′	C. C. 5° 00′	C. C. 7° 80′	C. C. 10°00′	C. C. 12°80′	C. C. 15°00′	C. C. 17°80′	C. C. 20 00
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
B.C. 2 80	....	0 11⅛	0 28⅛	0 52⅛	1 24⅝	2 08⅝	2 50⅝	8 45
C.C. 5 00	0 11⅛	....	0 22½	0 50⅝	1 26⅝	2 09⅝	8 00	8 58⅛
C.C. 7 80	0 89⅝	0 22⅛	....	0 88⅝	1 18⅛	2 00	2 54⅝	8 56¼
C.C.10 00	1 22⅛	1 01⅞	0 88⅝	....	0 45	1 85⅝	2 83¼	8 89⅝
C.C.12 80	2 20⅝	1 56⅝	1 24⅝	0 45	....	0 56⅛	1 58⅝	8 07⅛
C.C.15 00	8 88¾	3 05⅝	2 80	1 46⅞	0 56⅛	....	1 07⅛	2 20⅝
C.C.17 80	5 01⅞	4 80	8 50⅝	8 08¾	2 09⅝	1 07½	....	1 18⅛
C.C.20 00	6 45	6 09⅝	5 26¼	4 85⅝	8 87⅛	2 81⅝	1 18⅝	....

FOR TABLE 1.

Degree of Main Curve	"D"	"t"	Total Curvature in Tapering Curve at Each End of Main Curve	"d," = "D," less Radius of Main Curve	Long Chord from B. C. of Taper to C. C. of Main Curve
° ′			° ′		
1 00	5729.61	15.	0 09	0.00	80.00
1 80	8819.80	80.	0 27	0.06	60.00
2 00	2865.01	45.	0 54	0.17	90.00
2 80	2292.24	60.	1 30	0.87	120.00
8 00	1910.57	75.	2 15	0.66	149.99

FOR TABLE 8.

Degree of Main Curve	"D"	"t"	Total Curvature in Tapering Curve at Each End of Main Curve	"d," = "D," less Radius of Main Curve	Long Chord from B. C. of Taper to C. C. of Main Curve
° ′			° ′		
5 00	1146.11	15.00	0 45	0.10	80.00
7 80	764.48	29.99	2 15	0.40	60.00
10 00	574.12	44.97	4 80	0.99	89.98
12 80	460 56	59.98	7 80	1.97	119.92
15 00	885.68	74.82	11 15	8.48	149.76
17 80	888.20	89.62	15 45	5.48	179.48
20 00	295.04	104.27	21 00	8.20	208.80

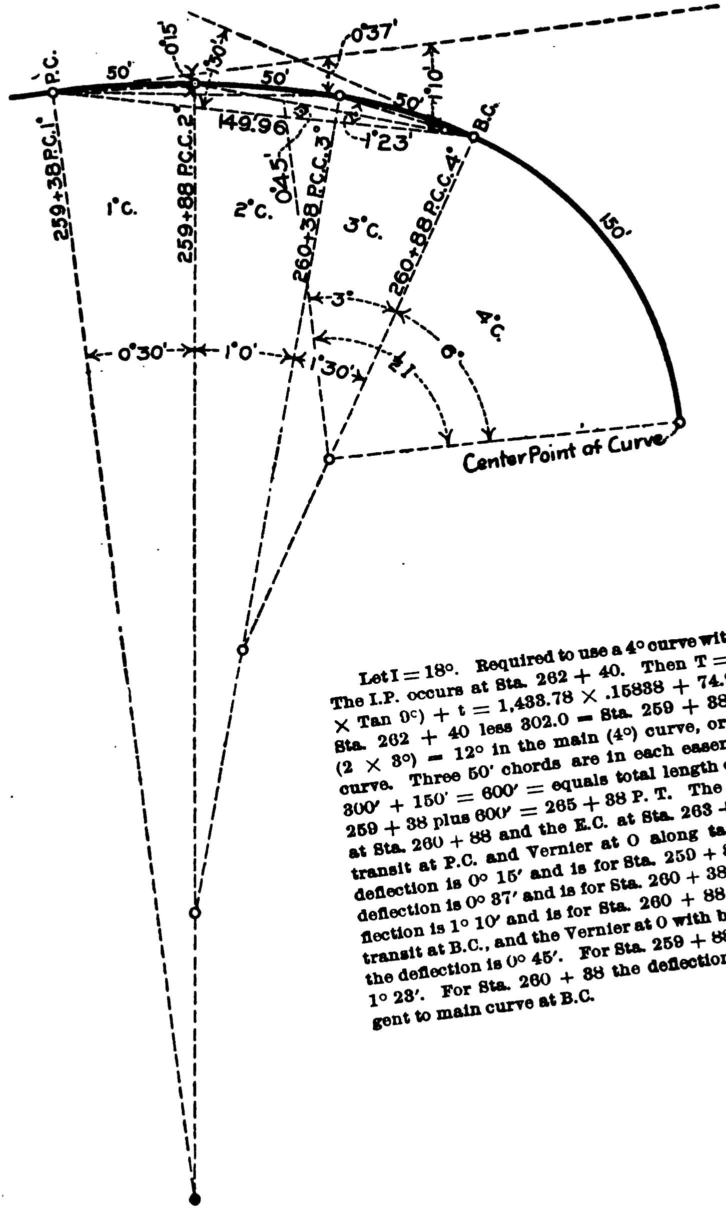
FOR TABLE 4.

Degree of Main Curve	"D"	"t"	Total Curvature in Tapering Curve at Each End of Main Curve	"d," = "D," less Radius of Main Curve	Long Chord from B. C. of Taper to C. C. of Main Curve
° ′			° ′		
5 00	1146.08	7.50	0 22⅛	0.02	15.00
7 80	764.18	15.00	1 07⅛	0.10	80.00
10 00	578.88	22.50	2 15	0.24	45.00
12 80	459.08	29.99	8 45	0.49	59.99
15 00	883.10	87.47	5 87⅝	0.86	74.97
17 80	829.09	44.94	7 52⅛	1.87	89.98
20 00	288.90	52.39	10 80	2.06	104.85

FIG. 41

EASEMENT CURVES.—Mo. Pac. Rwy. Changing 1° each 50 feet.

EXAMPLE



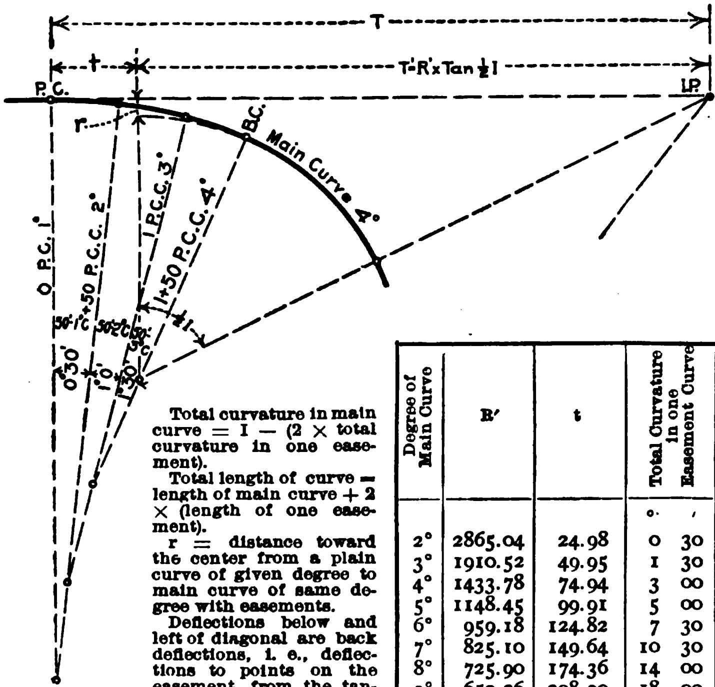
Let I = 18°. Required to use a 4° curve with easements.
The I.P. occurs at Sta. 262 + 40. Then T = T' + t = (R'
× Tan 9°) + t = 1,433.78 × .15838 + 74.94 = 302.02.
Sta. 262 + 40 less 302.0 = Sta. 259 + 38 P.C. 18° −
(2 × 3°) = 12° in the main (4°) curve, or 300' of main
curve. Three 50' chords are in each easement. 150' +
300' + 150' = 600' = equals total length of curve. Sta.
259 + 38 plus 600' = 265 + 38 P. T. The B.C. will occur
at Sta. 260 + 88 and the E.C. at Sta. 263 + 88. With the
transit at P.C. and Vernier at 0 along tangent, the first
deflection is 0° 15' and is for Sta. 259 + 88. The second
deflection is 0° 37' and is for Sta. 260 + 38. The third de-
flection is 1° 10' and is for Sta. 260 + 88 B. C. With the
transit at B.C., and the Vernier at 0 with back sight at P. C.
the deflection is 0° 45'. For Sta. 259 + 88 the deflection is
1° 23'. For Sta. 260 + 88 the deflection is 1° 50' for tan-
gent to main curve at B.C.

FIG. 41.—Continued.

Easement Curves.—Mo. Pac. Ry. Changing 1° each 50 ft. from Tangent to Main Curve.

TABLE.

Distance from I.P. to P.C. or P.T. $= T = T' + t = (R' \times \text{Tan } \tfrac{1}{2} \text{ I}) + t$.



Total curvature in main curve = I − (2 × total curvature in one easement).

Total length of curve = length of main curve + 2 × (length of one easement).

r = distance toward the center from a plain curve of given degree to main curve of same degree with easements.

Deflections below and left of diagonal are back deflections, i. e., deflections to points on the easement from the tangent when the instrument is at the B.C. or E.C.

Degree of Main Curve	R'	t	Total Curvature in one Easement Curve	r	Length of Long Chord from B.C. to P.C. or from E.C. to P.T.
			° ′		
2°	2865.04	24.98	0 30	0.11	50.00
3°	1910.52	49.95	1 30	0.44	100.00
4°	1433.78	74.94	3 00	1.09	149.96
5°	1148.45	99.91	5 00	2.17	199.90
6°	959.18	124.82	7 30	3.81	249.80
7°	825.10	149.64	10 30	6.08	299.55
8°	725.90	174.36	14 00	9.12	349.08
9°	650.26	208.90	18 00	12.99	396.07
10°	591.50	223.18	22 30	17.81	443.16

DEFLECTIONS

Inst. at	P. C. 0	C.C. 2° +50	C.C. 3° 1	C.C. 4° +50	C.C. 5° 2	C.C. 6° +50	C.C. 7° 3	C.C. 8° +50	C.C. 9° 4	C.C. 10° +50
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
P. C. 0	......	0 15	0 37	1 10	1 52	2 45	3 48	5 00	6 22	7 54
c.c. 2°+ 50	0 15	......	0 30	1 07	1 55	2 52	4 00	5 18	6 45	8 22
c.c. 3° 1	0 53	0 30	......	0 45	1 37	2 40	3 52	5 15	6 48	8 30
c.c. 4°+ 50	1 50	1 23	0 45	......	1 00	2 07	3 25	4 52	6 30	8 18
c.c. 5° 2	3 08	2 35	1 53	1 00	......	1 15	2 37	4 10	5 52	7 45
c.c. 6°+ 50	4 45	4 08	3 20	2 23	1 15	......	1 30	3 07	4 55	6 52
c.c. 7° 3	6 42	6 00	5 08	4 05	2 53	1 30	......	1 45	3 37	5 40
c.c. 8°+ 50	9 00	8 12	7 15	6 08	4 50	3 23	1 45	......	2 00	4 07
c.c. 9° 4	11 38	10 45	9 42	8 30	7 08	5 35	3 53	2 00	......	2 15
c c 10°+ 50	14 36	13 38	12 30	11 12	9 45	8 08	6 20	4 23	2 15	......

minimum, and at a certain curve Taper 1 or 2 or 3 is used, as desired. On the Missouri Pacific Railway it was the custom to set stakes at half stations 50 ft. apart on sharp curves. Here easements were most needed. The writer, therefore, computed an easement curve table for 50 ft. chords as simple an easement as possible, 50 ft. of 1° curve, 50 ft. of 2° curve, etc., were used until the degree of curve was attained as used on the central, main, curve, for example 6°. To facilitate its adoption a diagram was made, and to make it handy in the field the table was printed of a size to paste on a blank page in Butts' Field Book, and the explanatory diagram of a like size to paste to the page facing the table. (See Fig. 41.) The table is intended to avoid field computation of distances and to show all deflections on front sight. It was original with our locating party then, and we computed it in camp. We afterward learned that Mr. Hood of the Southern Pacific Railway was then using taper curves. No doubt Mr. Holbrook's spiral was computed before ours. The object of these Southern Pacific and Missouri Pacific curves is not to invent something new or rearrange something old. Their object is to compute fully and tabulate compactly a curve or curves adapted to the roads and to avoid field computation. The time of a field party costs about five dollars an hour.

COST OF CONSTRUCTION AND CAPITALIZATION.

Cost of construction enters into the question of choice of preliminary lines through the interest account. It is the earliest but often not the largest item in the capitalization of the line. It is determined directly from the map and profile by computation and has often been the only criterion on which choice of preliminary line is based. The principal items in the cost of construction are for Right of Way, Grading, Bridging, Track and Buildings.

Right of Way.

The amount of right of way required is determined directly from the profile. The length of the line and the depth of the cuts and fills give the length and widths of the right of way. In new country where land is cheap it is best to count right of way by the mile, adding to the length of line enough to balance the extra widths needed at points where the work is so heavy the usual widths of right of way is not sufficient. Since the cheapest time to buy right of way is at the inception of the line, it is best to estimate for liberal widths. A little extra width adds little or nothing to the cost. The law recognizes two elements of land damage, viz., amount of land taken, together with the value of growing crops, and damage to the owner's property by reason of the way the road runs through it. The latter is a matter of knowledge of local conditions. It is not acreage, but intrusion and jagged boundaries which owners of the land and commissioners for condemnation appraise at highest damages. A line that cuts through or near buildings will

obviously increase land damages. You buy at first by wholesale, when, if ever, residents wish the road. Retail buying at a later date costs much more per acre. On the other hand, it must be borne in mind that needless right of way for either construction or operating purposes is an increase of cost of maintenance of way with no compensating advantages. There are many western roads having a least right of way of 100 ft. in width when 66 ft., as a rule, would have been more economical. It costs to cut weeds and brush on unused right of way.

Where borrowing and wasting is the custom and overhaul not practical, the right of way width is not readily found. Experience must show when width of borrow pit or of spoil bank is cheaper than depth or height. The writer's custom on the Mo. Pac. Ry., after long experience and close watching of results, was to increase the width of the 100 ft. right of way for heavier than ordinary work as follows: Fills require no extra right of way added to the usual 100-ft. right of way until they are nearly 10 ft. in height. Our roadway in embankment was 14 ft. wide, slope 1½ to 1, beams 5 ft. wide. Banks 11 ft. high require 125 ft. right of way. For every 2 ft. added height add 25 ft. to the width of right of way. A bank 20 ft. high requires 250 ft. right of way. At about 22 ft. in height the embankment costs more than a trestle. When that point was reached we trestled the line and filled it with a steam shovel by the time the trestle needed renewing—say, six years. Cuts over 6 ft. in depth could not be wasted on the right of way. Our roadway in cuts was 18 ft. wide, slopes 1 to 1, berms 6 ft., surface ditch inside of spoil banks. We increased widths of right of way as cuts deepened more slowly than for banks, and according to material. Sand will not pile up as well as clay. Solid rock needs more room to get rid of the waste economically.

Cost of right of way is usually estimated by the mile save through towns or at special points where other interests are damaged. This cost per mile in new countries can be estimated as closely as any other construction cost. Extra widths are frequently estimated by the acre, ten feet in width of right of way per mile requiring very nearly one and one-quarter acres. This ratio is also used in converting right of way miles to acres. It is not prudent to estimate low on right of way. Experience has shown that this cost is often underestimated.

Occasions arise where cost of right of way controls the location regardless of all other construction costs. This is a local condition, often occurring in cities. Here the cost of right of way should be learned by a real estate agent and not by a locating engineer.

Cost of Grading.

The cost of grading is usually estimated directly from the profile and the current contract prices. It is usually considered that clearing and grubbing are so intimately related to grading that it is

a subhead of the grading account. The levelman as well as the topographer keeps notes of the station and plus where clearing must begin and end. The right of way area between these stations gives the amount of ground to be cleared. Clearing or grubbing is estimated and contracted for by the acre. Grubbing is usually considered to be that part of the clearing area within the slope stakes of all cuts and such fills or parts of fills under five feet in height. Sometimes clearing and grubbing is a separate item in contracts. In this case, the area is the clearing area, the grubbing necessary being included in the contract price. Some times, where the two kinds of work are separate, the grubbing is estimated and contracted for by the station. Local customs rule in this matter.

The grading quantities are estimated approximately. Accuracy is not required, but the same relative accuracy for each line is necessary. Use the easiest plan at hand. Do not compute the cubic yards in the grading at the ends of bank at bridge openings but consider the bank solid to the toe of slope. This makes it necessary to leave out the "clear openings," i. e. distances between foot of slopes. This gives the grading an excess but there is always extra grading outside cross sections. The amount of grading to be allowed for ditching each section must be estimated. In estimating grading where "classification" occurs within the station, a supplementary computation is necessary. It is wise to keep the total number of cubic yards correctly for the section and vary the proportions of each, later, according to "classification" notes. When overhaul is paid for, it must be taken into account, but it is unwise to try to get this comparative estimate more closely than its purpose requires. Since "classification" so radically alters prices of grading per cubic yard,—earth, loose rock and solid rock being in price at about the ratio of one, three and six,—it needs attention.

The "classification"[1] is determined from the notes of rock outcrop as kept by the levelman and from the notes of the topographer as a check together with his estimate of the amount of earth over-lying the rock, and last, but not least, from the judgment of the chief of party based upon his wider observation of the country to the right and left as to the depth of the ledge rock below the earth surface. This last largely depends upon the inclination of the rock strata of the region. In short, after exhausting all possible means of observation and study, the chief of party must use his judgment in "classification," as in so many other matters. Test pits are sometimes dug down to the rock to learn the depth of overlying earth, which is of course the safest procedure. It is easier to estimate where the earth ends and the rock begins and draw the line on the profile than it is to estimate where loose rock ends and

[1]Classification primarily meant the separation of excavation yardage into two or more items, such as "earth," "loose rock" and "solid rock," a separate contract price being paid for each. It now means any material other than earth—such as hardpan, loose rock, solid rock, etc.

solid rock begins. The different materials must be shown on the profile before estimating and kept distinct from each other. Computing the total cross sections as earth and then "allowing for" solid rock and other classifications leads to wild guessing, as the writer knows from experience. You are naturally in a hurry, but either arrive at your best estimate of quantities in a safe, rational way in which you feel confidence, or else look carefully over the profile, forward and backward, a few times and then write down the averages of each item of grading and all other costs of construction per mile for that preliminary. Your assistant can then multiply the average by the number of miles and your guess is complete.

There are two ways of arriving at the cost of a line, viz.: estimating and guessing. The writer believes it to be the duty of a chief of party to estimate before deciding between two fairly closely balanced preliminaries. To estimate means to gather carefully all approximate quantities from as reliable sources as possible on the ground, and work up these results from his notes and the notes of his party, supplemented by his own best judgment at the time. This is a preliminary estimate in the field, and should be a safe criterion for the investment of capital. A guess is well enough for engineers higher in rank and of longer experience than a chief of party. Guesses are often close, but he is brave who invests money in them. Any man who wastes time in estimating in part and guessing the rest is surely foolish. You are sometimes obliged to guess on reconnaissance, but when you are in doubt you run a preliminary. If you then guess at the result on that preliminary, what have you gained? Always *estimate* on a preliminary. Experience has shown many chiefs of party that in balancing the advantages of two preliminaries by estimate the result is surprising. Guessing and estimating each have their use. But never mix them. Use one at a time. An engineer who has estimated for some time is the only one who is safe to do guessing. An engineer who has done a good deal of guessing usually avoids guessing whenever he can. Glancing carefully over a located profile for 100 miles and guessing at what it will average per mile of grading in total cubic yards is closely done by old construction engineers.

Having the lines of demarcation of the different materials on the profile, you are now prepared to estimate the cubic yards of grading. The widths of the roadway used in cut or fill being known by the company custom, the cubic yards per station of 100 ft. may be read at once from tables of level cuttings. That the ground is level transversely is assumed in these tables, and the error is ordinarily small in doing so. But on ground having a steep transverse slope such assumption is disastrous; then side heights and side distances must be got from slope notes. Earthwork diagrams are much used of late years in preliminary estimating, and by some are used on final estimates. Except in special cases where side

slope notes are needed, the writer has used for a long time a scale, Fig. 42, made of a piece of the profile paper. One man reads it midway between stations, estimating to the nearest half foot. He keeps the zero of the scale on the grade line as he goes along and calls out the station cubic yards of that 100 ft. in cut or fill. The scale gives the cubic yards per station corresponding to the depth of cut or fill on the profile, for a given width of roadbed. He calls out the end of the section, and sections are recorded sep-

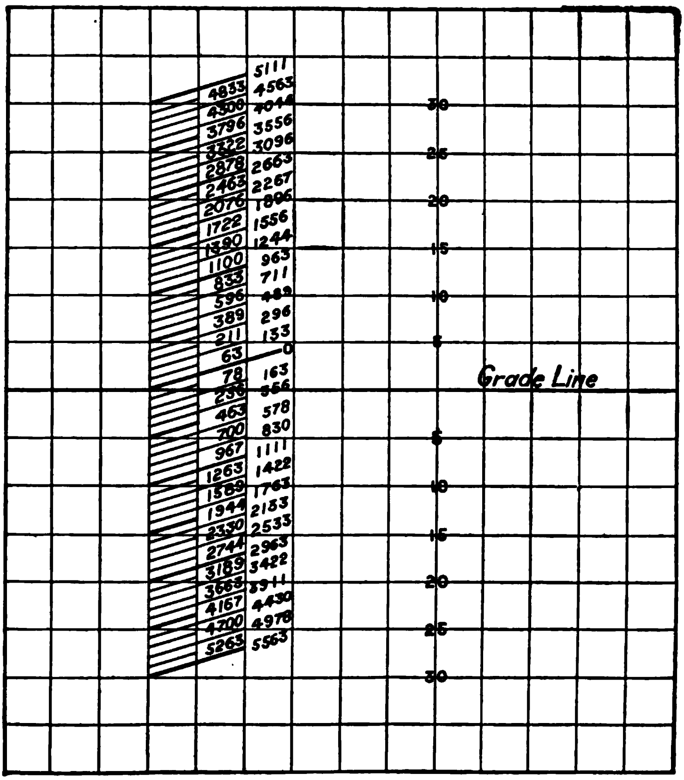


Fig. 42.

arately. When classification is shown on the profile a table of level cuttings is used, usually supplemented by calculation. A rock scale can be used corresponding to quantities per station for a roadway and a slope in rock cuts. This scale method is very quickly used and is safe when intelligently used. In estimating cuts a liberal interpretation of the scale must be used to cover ditches. Where the rock is thought to extend down to the grade line, sub-grading is needed. Hold here the zero of the

scale one foot below the grade line. Along fills there are always some ditches for which to provide. Small trestles reduce the cubic yards of grading, but that is not taken from the grading quantities, ordinarily. The cost per cubic yard for each class of material in the company's specifications should form a part of the instructions of the locating engineer or chief of party. It is usually the price paid on the last contract in that locality.

Masonry.

Masonry is next estimated. The standard plans for culverts of the different sizes must have the number of cubic yards in end walls for each and a separate quantity for the cubic yards in the barrel of the culvert per foot of length. Cubic yards in end walls being known, you have but to compute the masonry in the barrel of the culvert at the known amount of masonry per foot for the length of culvert between the slope stakes. This gives a small excess in length, but is the safe plan to provide for contingencies. Bridge masonry must be computed from a rough sketch made at the time, following the general plans of the road. The cost of iron or vitrified culvert pipe with their masonry ends belongs in this item. Since all the items so far considered are supposed to be permanent and indestructible through age, they are cost items chargeable directly to the capital outlay for the road. No capitalization is necessary therefore. In construction parlance an "opening" is a gap in an embankment usually to carry water. Bridging is any structure built in these openings.

Bridging.

Ordinary bridges, unlike grading or masonry, perish with age. They must therefore be capitalized: The cost of bridging varies greatly. We assume that the class of bridging is indicated in the instructions. Locating engineers are criticized more for inadequate bridge spans and clearance than for all other errors of construction. Engineers differ most widely on this point. It is pertinent here to say that in estimating the cost and relative value of preliminary lines, bridging where needed must be placed at a higher estimate than the locating engineer is inclined to make, for he naturally wishes to protect his line from useless cost. Suffice it to say that no bridge opening should be smaller than nature now uses at that point. Overflow channels at large streams having wide bottoms must have a bridge or trestle provided for them. On long, high banks sometimes, and on embankments across overflowed ground always, openings and bridges must be provided at quite regular intervals. For example, it is best on many river bottoms subject to overflows to put in a pile bridge every 1,000 ft. An embankment carrying railway trains cannot safely have head of water on one side above the level of the water on the other side. Amount of opening is not the only requirement. Frequency of opening is sometimes neces-

sary. A current always needs bridging, but slack water must not be allowed to pile up. It must have vent to prevent head.

For the smaller openings, such as culverts, it is sufficient for preliminary work to make them twice the size that nature would seem to have filled thus far. Cultivation, slope, etc., modify so largely this question that any rule of practice is hazardous. Do not use ditches to lead to a culvert from where a culvert seems to be needed. This is a common error. You may ditch to a bridge, but even then a ditch of any length costs too much to keep clean.

A new line of railroad, being usually in a country having light traffic and far removed from a variety of construction materials resorts to many devices for solving bridge problems. There is not time for erecting iron spans. There is not good rock for masonry at all points. Every possible device of "closing an opening" is used, such as pile bridge seats, trestle work on piles, cribbing, wooden boxes to later allow iron pipe to be dragged through them, culvert pipe, French drains, etc. The engineer's problem simplifies itself by at once considering each bridge to be the kind needed as a permanent structure. Disregard entirely any temporary structure, whether that structure is expected to be replaced in thirty days or three years. We are not now speaking of pile or trestle bridges. Leave construction devices for the saving of time entirely out of the economic question, and let them justify themselves. Charge to the proposed capital account of the preliminary line the permanent bridge structures. Count upon iron spans, plate girders, arch bridges, stone culverts, iron pipe culverts, etc., and do not count in false work, wooden piers, temporary trestle, temporary timber culverts, etc., where iron and masonry structures are intended later. This presupposes that girder bridge prices are prices in place, including false work. This view of the case is fairer than it would seem, for much of this temporary wooden bridging is used until it is too old to be safe, thus saving the interest on the permanent bridge. Much of such bridge timber is used again. Furthermore, a line should not be charged with two bridges for one opening, one temporary and one permanent. Moreover, a company changes its plans, and if temporary bridges are computed and the plan is changed to permanent ones the preliminary estimate (too often taken for a final one in our haste for construction) is found to be too low. This is the general law of estimates. Estimate as close to the actual as you can, but never estimate too low in cost or too short in time. "Every line he ever built for me was completed within the estimated cost and by the date he fixed before work began," said Mr. Jay Gould of a late head of his engineer department of the Missouri Pacific Railway. Such an engineer aids a president. Permanent bridges have a closer known cost than temporary ones, and from every possible standpoint the writer has found this plan to be fairest, closest and safest. But this does not forbid using pile bridges or wooden trestles and capitalizing them.

Bridge Spans.

Obviously we may pass over suspension bridges as being outside a railroad problem. Enormous spans, as at Memphis, are not contemplated here. And we shall regard draw spans on navigable streams as being so far within the province of the government as to be an arbitrary and not an economic bridge problem. Our largest bridge is therefore one consisting of a series of spans. The first question is the economical length of span. The writer is indebted to one of the eminent engineers of this country, whose special work in his company was preliminary bridge estimates for this general rule for length of economic bridge span: "a span which costs the same as a pier for that bridge has the economic length of span." An iron span is considered to have a masonry pier. Concrete is replacing stone masonry where no ice forms and drift is not too heavy. Concrete is then cheaper and better where rock is not good. In estimating piers the difficulty is in the foundation. Soundings for rock must be carefully made. If you estimate for masonry founded on rock by pneumatic work, if below water surface, you are safe. Such work has a known cost. No one ever knows before hand what cribs and cofferdams will cost, or how long it will take to get them down.

The cost of steel truss spans of various lengths must be known. The length at which truss spans cease to be used and the longest plate girder spans are used instead must be known. Of late girders are used for 90 ft. length and less. Costs of girders of each length must be known.

Wooden truss bridges are less used than formerly. They differ none from iron trusses in estimating, save in renewal account.

Pile Trestles.

Pile and trestle bridges are unlike iron bridges. Their span is fixed by the standard plans of the road (13 ft., 16 ft., etc.), and their cost per 1,000 ft. B. M. does not vary from time to time. The height of "bent" is variable with the profile, and offers difficulties in any reasonable preliminary estimate. For pile bridges the writer proceeded in this way: One span or "panel," say 14 ft., contained in the cap, stringers, tires, guard rails a certain number of ft. B. M. Each pile opening contains a certain multiple of this quantity in ft. B. M. for the deck. The number of bents being known by the size of the opening and the number of piles in a bent by the standard plan. The pile length is known by adding the penetration of the pile to the distance from ground to grade by the profile. This leaves the depth of the cap and stringers for "brooming."[1] The average penetration depends upon the ground. In high prairie

[1]Brooming is a term applied to that length of a pile at its upper end which is destroyed by the pile driver's hammer.

it is about 8 ft., and 10 ft. is safe for most lines. In case of short bridges showing channels, an average can be taken for several bents, or all of them at a time. Mark the ft. B. M. and the total lineal feet of piling on the profile at each opening.

For trestle bridges the same plan is followed for the ft. B. M. in the decks. If bents rest either in part or all on piles they are thus far pile bridges. But the bents of a trestle bridge increase in ft. B. M. by a greater ratio than directly as the height. It is safe to compute the ft. B. M. in the trestle of the standard plan for each 5 ft. in height, out to out, and tabulate this. Then use the bent nearest to the required one in each case, using the higher bent in case of doubt.

False Work.

Regarding false work and all temporary structures that will in a short time be replaced by permanent structures, we need mention but two to make the question clear: (1) The pile or trestle false work, which may or not carry trains, and is used in the erection of a span bridge before the false work's lifetime ends through decay; and (2) the wooden box in an embankment through which iron pipe are laid at the expiration of the lifetime of the box. It was the custom of the writer to charge against the proposed line the entire cost of the temporary structure, but no capitalization for its renewal, and also to charge the entire cost of the so-called permanent structure with its necessary capitalization. The false work timber at the span bridge can be used again, but it costs to get it out, and its depreciated value through splitting, etc., is hard to estimate. As an offset to its value is the liability of losing it through high water before the span is swung. It is true that the wooden box during its lifetime serves as an opening, but it costs more to drag the pipe through it than it would to put in the pipe before the fill was made. Are not these temporary structures devices to save time of construction, and do they not entail risks and losses and expense to the road in the operation? When we propose to use temporary structures we must spend something for insurance and for contingencies. To charge both temporary and permanent structures at once to the line is a clear-cut plan. It may err, but it errs on the safe side. It might be asked, should we estimate for a wooden trestle 100 ft. in length and its capitalization for renewal and then charge also to the line the 10-ft. stone arch and the embankment over it which replaces in years to come this wooden trestle. The answer is "no," for we have already charged the line with the cost of the bridge and the capitalization for its renewal. This insures means to make the structure perpetual. If the company finds that for a less first cost than the capitalization of the trestle bridge they can build a stone arch and the fill over it, then they will do so, "because it is cheaper."

Capitalizing a Trestle.

Assume, as is the case in some localities and with some kinds of timber, that only trivial repairs are needed during the first four years of the lifetime of the trestle; that the fifth year considerable repairs must be made, and that after the tenth year little of the old bridge remains. On computation we find (we will say) that the average length of time the capital was invested in that bridge is 6½ years. Let us assume that hereafter, as in the past, the lifetime of the bridge is 6½ years. To make the bridge perpetual we must set aside sufficient capital such that the interest at the market price for our company will create a fund every 6½ years sufficient to rebuild the bridge. We must, therefore, add to the cost of construction this capitalization. Our bridge represents, first, capital invested to build it; second, capital set aside, the interest of which will rebuild the bridge when necessary through decay. Caution must be taken here. Original construction is often greater in cost than reconstruction, and it is, of course, cost of reconstruction for which we capitalize. Suppose a pile trestle costs $7 per lineal foot to construct. It may be rebuilt for $5, and when the old usable material is credited to the bridge (as it must surely be) the cost of reconstruction is apt to be less than the first cost. One foot of bridge costing $7 to build and $5 to rebuild at the end of each 6½ years demands, first, a capital investment of $7 for each lineal foot of this bridging, and, second, another capital investment sufficient to yield $5 in interest for each lineal foot of this bridging at the end of each 6½ years. We will assume that it costs 5% for our company to hire money, i. e., its 5% first mortgage bonds now sell at par. From a compound interest table we find that $1 at 5% compound interest for 6½ years will amount to $1.37. Hence, to acquire $5 under the same conditions $\frac{5.00}{1.37} \times \$1 = \$3.65$ is required.

But to secure the $3.65 needed to make good the capital at the end of 6½ years requires $\frac{3.65}{1.37} \times \$1 = \$2.66$. Adding to $3.65 (the amount needed to be invested to secure $5 in 6½ years) the $2.66 (the amount needed to be invested to secure $3.65 in 6½ years) we have $6.31 as the capital value of one foot of pile bridging. This, added to the cost of construction, $7, of the bridge gives the total capital $13.31, needed to build and forever maintain that bridge. All structures which decay must be capitalized in this way.

Of course, small openings, cattle guards, road crossings and fences need to be capitalized. False work for span bridges, wooden boxes to be replaced by iron pipe do not need to be capitalized for reasons already given.

Minor Openings.

Bulkheads are either pile or trestle bridges of one span. Undergrade crossings (farms or roads), as well as overflows for tank ponds are also either pile or trestle bridges. Cattle guards and road crossings have quantities of material as per plan.

For the covered openings, culverts, pipes, etc., close estimates are not so readily made. Their locations are not so well defined by nature, and the location changes their lengths materially. Since in all cases of doubt the capital must be given the benefit of the doubt, it is best to count the length of a covered opening as the full distance between the slope stakes at the deepest place where it may be reasonably located. This puts the end walls entirely outside the slope, too far out for construction, of course. Having computed previously the quantity per lineal foot in the "barrel" of the culvert, the length of that "barrel" is the distance between slope stakes. The end walls are a constant quantity for a given size of structure. A pipe culvert with masonry ends is treated similarly.

By tabulating these few quantities as indicated for each standard plan of the company to be used on your line, the quantities and classes of material at each opening are readily calculated and placed in full on the profile at that opening.

Track.

The cost of the track is computed upon tons of rail, pounds of splices and bolts and spikes and number of ties per mile, each at the market price with freight added. Cost of track laying per mile must be added, and a liberal allowance made for that amount of surfacing a new track needs for the first months of its use. Since a telegraph line is now always built, its cost per mile may as well be added to the cost of the track. If fencing is needed it is computed with the track, like the telegraph line. Having obtained the cost of track and telegraph line per mile, with liberal allowances added, it is best to convert this to cost per foot. It is easier used that way, and becomes a multiplier of length of line in feet, the unit in which two preliminary lines are compared. For a term of years the track was counted as costing $1 per foot on Mr. Gould's Southwest System. This figure was too high, save when the heaviest rails and thickest ties were used, but it was a convenient multiple, and on the whole safe and wise. The sidings are estimated to cost the same price per foot as the main track, measured between head blocks. The cost of the main track ties which they replace about covers cost of putting in switches.

Should track or any track material be capitalized? It is seldom done. The idea has prevailed that mileage increases revenue, since passengers were supposed to be counted by the mile and freight by the ton-mile. For local business this is true to-day. For through business it is not true to-day. Again, traffic and not

time is supposed to destroy track. Its life is computed by tonnage over the track and not by the months it endures. It is not plain whether track should be capitalized or not. To capitalize it is a problem not differing from that of a pile bridge, just explained. We can count the average life of the track, or we may consider metal and wood members separately. Finally, we may take the cost of maintenance per mile per year and capitalize that by setting aside an amount which at simple interest will yield a revenue per mile sufficient to maintain and renew the track at the average yearly cost. To give a clear view of the relative costs of items it may be said that for the average mile of track of the United States the cost of maintenance is $425 per annum. Ten per cent. of this is for rail renewals, 20% for tie renewals and the remaining 70% is for track labor. It is quite clear that tonnage and not time destroys rails and rail fastenings. It is plain that time aids to destroy ties, if, indeed, it be not the major cause of it. Rails do not cut in two; the ties often do. Increase of car tonnage does not to a marked degree shorten the life of a tie. On many roads the average tie has the same length of life as the average bridge timber.

Buildings.

While it is doubtful that any difference in the number of buildings would ensue from the choice of any two lines under consideration, we shall say that a building differs in no way from a bridge. To its capital cost must be added the capitalized cost of its renewal at the expiration of its lifetime, if it be of wood. If of masonry, the walls are perpetual, but other portions perish through decay. By far the greater number of buildings are of wood and are treated like wooden bridges.

CAPITALIZATION.

Structures, as we have seen, must be capitalized. Follow, therefore, this rule of practice: Where you use structures having different lengths of life or requiring different percentage outlays for repairs, there must be added to the cost of each structure an amount, the interest of which will pay repairs, and also a second amount, the interest of which will pay for renewals. For example, as often happens, you propose using many pile bridges and some steel spans on masonry. The steel spans and their supports should last 25 years with little repairs and no renewals save in ties. The pile bridges are much shorter lived. Suppose a certain pile bridge costs per estimate $1,000. Suppose that experience with such timber in the given climate has shown that $100 must be spent in the fourth year for repairs, the same for each succeeding year up to the seventh year. Add then to $1,000 first cost, an amount of capital which put at interest at the market rate of your company (say 6%) at the date of construction will amount at compound interest to $100 for the fourth, fifth and sixth years of the

lifetime of the bridge. Suppose again, that experience has shown that that pile bridge must be renewed the eighth year. Add, then, to the $1,000, plus the obtained sums as above, such another sum as will produce at compound interest at your market rate an amount equal to the cost of renewal, say $800. The first cost, plus the capital which produces each repair cost by its compound interest, plus the capital which produces the cost of renewal by its compound interest is the capital needed to make that pile bridge perpetual. If the iron bridge on masonry piers lasting 25 years be similarly capitalized, it is then comparable with the pile bridge. A stone arch bridge is considered perpetual, and no amount need be added to the first cost to make a capital account to make that bridge perpetual.

We have considered the question of track capitalization and have seen that there is a difference in views. The rail should not be capitalized, for traffic destroys it, not time. A rail upon ties over which no tonnage moves is so long lived that it may be considered permanent. The same is true of switches and joint fastenings. But a tie is acted upon both by time, through decay, and by tonnage. On some roads, notably some parts of the Southern Pacific Ry., the tie is so nearly cut in two by the traffic that it must be renewed before it decays. The tie is redwood, a soft wood, and the climate unusually dry. Still, as a rule, ties decay and do not wear out. The chief engineer of the Texas and Pacific says oak ties last an average of five years. On the Iron Mountain Division, the Mo. Pac. Ry., oak ties last six years. It is a reasonable practice to capitalize only the ties of the track and consider the metal track members permanent.

While buildings surely decay, they are not capitalized unless to see whether wooden or masonry is the cheaper in the end. A depot is designed to invite and facilitate traffic. By the time it decays it has usually passed its usefulness, and a depot of a different character is demanded. You might capitalize a crossing flagman, but not a station agent. You would capitalize a bridge, but not a depot. Whichever of the two preliminary lines is used, we may assume the same local traffic and local depots. On any other basis we are dealing with traffic and not capitalization.

Since the company must depend on that small margin of profit lying between total earnings on the one hand, and total operating expenses, plus total interest on bonded indebtedness, on the other hand, it is easy to see that the price of capital in the market is a large factor in our problem.

If we borrow at 3%, the rate at which the L. S. & M. S. have now refunded, it is obviously economy to capitalize higher than if we must pay 5% for money. A higher first cost is therefore generally more economical in America than twenty years ago. For this reason it is often economical to revise a location which was correctly made a quarter of a century ago.

The fallacy that "the best is the cheapest," and therefore always desirable in location and construction, has injured many railroads and brought civil engineers into disrepute as railroad men. An expenditure by the Missouri Pacific between St. Louis and Kansas City with a view to lessen distance, lighten curvature or flatten gradients, may be economical, while doing the same thing between Fort Worth and El Paso would be suicidal. Again, a certain betterment of the above kind made by the Chicago and Alton on its longer line between Kansas City and Chicago might be justifiable, while any such expenditure by the Atchison, Topeka and Santa Fé on its shorter line there would be false economy.

The principle of capitalization has the widest application in railroad construction. Through blindness it has been little used. It is the principle which has given us heavier and again still heavier rails. It is the principle which causes lines like the Pennsylvania and Lake Shore to build stone arch bridges with the greatest care, replacing metal bridges. It is the principle which is removing all wooden bridges East and replacing them with steel ones, and it is filling in trestles on Western lines, after hauling rock hundreds of miles for a culvert. The locating engineer uses the principle of capitalization far too little. It is the wide-awake superintendent or the wise president that appreciates its force. It has made dividends possible on classes of stock that would otherwise be hopeless.

When revising the grades and curvatures of a line in operation, fewer assumptions should be made, and costs from actual operation may be secured. To-day we are having some excellent instances of the application of these principles.* It is best to work out each problem by itself and on its merits, using the foregoing general principles where observed costs are not obtainable.

PART II.

The Located Line.

Making the final location consists in so modifying the right preliminary line as to adapt the grade line and the center line to the traffic and to the topography. Engineers who advocate office location from preliminary surveys lose sight of the fact that to find a good line and recognize it as such is the highest form of the art of location. That is why a locating engineer must be a field and not an office man. An office man can choose between two preliminary lines found, but he cannot insure the company against passing by much better lines that the field party failed to find. Has office location no use? It certainly has use. All needed

* See "Reduction of Gradient and Elimination of Distance, Curvature and Rise and Fall on Union Pacific Railway," by J. B. Berry, Chief Engineer. A paper read before the M. of W. Association, Chicago, March 15, 1904.

preliminaries being properly compared and the best one selected, the chief of party should make an office location, station by station, with the map and profile in his hand as he is walking over that best preliminary. A good locating engineer can make a good paper location with the ground under his eye. This is an office or a paper location. There is no other person, no other place and no other time for an office or a paper location.

The early standard of comparison of two preliminary lines was the relative cost of construction of the line. The first advance from this plan was to give a value to the saving of distance. Until more recent years nothing more was attempted. Given two preliminary lines, A and B, the cost of right of way, grading, bridging and track was computed for each. But we find line B the shorter line, by say 1,000 ft. We then value that saving in distance, as directed by the instruction of the Company or the chief engineer. If that value be $12 per foot, then we deduct from the cost of construction of line B, $\$12 \times 1{,}000 = \$12{,}000$. The remainder we compare with the cost of construction of line A. We adopt and locate whichever line (A or B) is then the cheaper.

In former days the value of saving one foot in distance was given to the locating engineer as a part of his instructions. For branch lines of the Missouri Pacific Railway, in the State of Kansas, in 1886, the writer was instructed by the head of the engineering department to use $5 as the value of saving one foot of distance. The same value applied to Nebraska. In Missouri $6 was the estimate put upon the value of saving one foot of distance.

On the Atchison, Topeka & Santa Fé Railway, in its Chicago extension from Kansas City, the value of saving one foot in distance was placed at $21 in the State of Illinois, and $22.25 in the States of Iowa and Missouri, according to the letters of instruction to a locating engineer shown by him to the writer. By popular report the Pennsylvania Railway values one foot of distance at $50—presumably on its main line. These cited instances simply give a general idea of the range of values placed upon the saving of a foot of distance by our different roads in their certain districts. There is danger that such values be used over too large a district and over lines too diverse in density or class of traffic or kind of competition. This custom is a long stride in advance of using no valuation for the saving of distance, but it falls short in vital directions. Suppose line A has a 1% gradient, and line B a 1.25% gradient as a maximum. No rational engineer would consider the lines comparable on the mere basis of first cost. Suppose again that line A has 90 ft. more rise and fall than B, and each has the same maximum grade, how can this overplus of rise and fall on line A show a balance in dollars and cents in favor of line B? Finally, if line B has 150° more curvature than line A, what should be added in dollars to line B, to allow for the cost of hauling trains over 150° of curvature?

In 1877 there appeared the advance sheets of a small volume by the late A. M. Wellington on "The Economic Theory of Railway Location." The present writer, then a Junior in college, was taught from these advance sheets which represented a pioneer effort toward wiser choosing of economic preliminaries and located routes for railways. The book was in advance of its time. The writer believes it to have been the first work on the subject in any language. Most engineers failed to understand it. Few used it, and they but sparingly. These few were the younger men.

But there came a change in methods, and as that author very clearly laid down the fact that 600° of curvature equaled in train resistance one mile of straight, level track, we offset one against the other, i. e., 600° = 5,280 ft., and this was used in comparing resistance of preliminaries. It was crude, but it provoked thought, and thought could but lead to wiser deductions. The value of curvature and rise and fall we have already considered.

LOCATING FROM ONE PRELIMINARY.

We shall now consider the practical problem of locating a line when but one preliminary line has been run, and no more needed. This is the ordinary case in easy country. This single preliminary should always be run on as direct a line as the country will practically permit between the controlling points. This preliminary must here be assumed to be unquestionably on the right route and close to the right line, all of which the reconnaissance work has shown beyond a doubt. Let us assume that the instructions require the located line to be run as well as the preliminary lines, and that the nature of the country permits the located line to be carried on from point to point just behind the preliminary line. When the country will permit it, and good reconnaissance work be done for a long distance in advance, this method is safe and economical. This method includes those cases where more than one preliminary is needed for short distances at a few difficult points.

Consider, then, that from the camp assumed to be located for the purpose of starting the preliminary line from the initial point, a preliminary line has been run as far as the first controlling point after the initial point. This controlling point is one fixed by the topography—a secondary controlling point. Suppose that this point is fifteen miles from the initial point, that the one preliminary needed is being completed to-day to this secondary controlling point by the line party, and that camp has not been moved. It was known this morning that the next day's work would be on located line. All of the preliminary line has been mapped and the profile platted save this last day's running necessary to reach this secondary controlling point. In this case, chosen for its simplicity, what is to be done to locate a line?

The first thing to be done is for the chief of party to walk over the ground, following the preliminary line and studying the map and profile of it as he goes. If there be any economical way to locate a line without the engineer in charge of the locating party going over the ground with the map and profile of the preliminary in hand, and learning on the ground and marking the located line in that way on the preliminary map, the writer does not know of it. This one principle of railroad location is imperative. It is not paper location nor is it location on the ground. It is both, and it is more economical than either used separately. There is little fear of an experienced locating engineer criticising this method for general use in ordinary country. To study the ground with the preliminary map and profile, one requires a knowledge of topography, good railroad sense, and the constructive faculty. By the latter, is meant the ability which enables one to see a bridge or building clearly from the plans, or it is that faculty which in students is shown in aptness for descriptive geometry. The chief of party may have drawn previously a line which seems by the map feasible. If so, he examines the problem with that line also in view. In the general case—it is the profile that usually gives trouble. The map, as we have said, for easy country should show a direct line with few and moderate angles.

Preliminary tangents in easy country should not be broken up for short or slight difficulties, because offsetting and breaking up tangents increases cost of preliminary and makes computed long tangents more apt to be in error. Keep to your tangents, but "chop" your grade lines, and the cost as estimated by that preliminary will be correct and obtained at the least expense. Grades and heavy work usually make it desirable to break up the preliminary line slightly on location. Often this is done by "hinging" a tangent, that is swinging it on one end as a fixed point until the other end is, say, 20 ft. lower at Sta. 35. It then remains to find how far horizontally this point 20 ft. below Sta. 35 is from Sta. 35. With the hand level, sight at the foot of stake 35, and move backwards down hill from it at right angles to the tangent. Assume, for example, that your eye is 5 ft. from the ground. When the bubble shows level and the cross hair cuts the bottom of the stake, you may lay your map or other object to mark the spot where you are standing. So proceed until you find four points, each of which is 5 ft. lower than the last—a total of 20 ft. Pace back, say 250 ft. to the stake, gathering up your map, etc., and mark the profile at Sta. 35, "Grade 250," right or left. It is best to put this mark above the ground line on the profile when the distance is measured to the right and below when to the left.

In difficult country a rodman is needed, and he keeps the distance by pacing, but where one preliminary is needed the chief of party can fit the line to the ground unaided and record his work on the preliminary map and profile.

On a "supported line"[1] (Plates 6 and 7), it is best to take these distances to grade points at almost every station, recording the distance on the station of the profile, above or below, according to convention. It is often desirable on supported line to offset a tangent parallel to its preliminary direction. Errors of distance as estimated in reconnoissance will cause this, or an error in an estimate of the curvature will do so. Such offsets are not so great that the hand level will not show readily just what the cut or fill will be in advance of any located line being run. An offset is frequently not parallel. Keeping one station along the preliminary tangent as a fixed point, and swinging one end of the located line to the right and the other to the left is called "pivoting" the tangent about that particular station. This could hardly be called for in long tangents properly run at first. Using, then, the preliminary tangents as a framework, the located tangents are designed to be attached to them one by one. Pivoting, hinging, parallel offsets, and angle offsets are the common means of relation between preliminary and located tangents. The idea should be not to deflect preliminary tangents for minor obstacles, but break up the preliminary tangents somewhat in locating the line.

The profile contains the greater part of the field notes taken during this examination. It shows the changes in elevation of surface and direction and amount of offsets to those changed elevations. The map should have marked on it the points where the new angles are to be turned with the distances to them from some designated point in the field. It is best to plat these new points on the map in the field as they are decided upon. The distances should be marked as well as scaled. It is usually not wise to draw in the lines in the field if they be long ones, and it is well to omit them entirely if the angles do not need to be measured in the field. In this method of work a preliminary map and profile are not records. They are tools, and do not really need to be preserved. Notes must be written on the preliminary map and profile without stint. Besides the hand level, and possibly a level rod, there is needed a prismatic compass. For platting, use a rectangular protractor, a scale, and a folding pencil point compass. These instruments are about all that the pockets need to accommodate at any time. The longer an engineer uses this method, the more notes he makes and the more he depends on field observation, and field platting. There is no assumption about it. The ground is before you, and you see the cost you incur or save.

[1]Plates 6 and 7 show map and profile of a line of the C. & N. W. Ry., near Peoria, Ill., located by the writer in 1900. It is supported in a deep valley whose earth sides stand at the steepest slope for that material—an earth canyon. The cuts exactly make the fills. The grading averaged 100,000 cubic yards per mile for the length of the maximum gradient. It is a good example of a supported line in heavy work. A supported line is one in which the ground line touches the grade line at all points; or it is a line where the cuts will make the fills within hauling distance.

The curves need but seldom to be drawn in on paper in the field. Large angles on preliminary lines should never be turned all at once, except in very easy country. A preliminary line showing large deflection angles and short tangents is self-condemned. The preliminary tangents should be as much chords of the located curve as they are tangents of that curve, and they should be so short as to lie on the average ground of the located curve.

Offsetting and shifting tangents, as already described, are not the only changes possible, of course, but they are the most common changes. We may run by a tangent. This may occur where a deflection was made at an obstacle which required no deflection and where the former tangent should have been continued beyond. The more creditably the preliminary work is done the more nearly will the located line be an offset; nearly parallel to it. And that offset will represent a pardonable error in estimating the curvature to be equated for on the length of the maximum grade used. For the easy country which but one preliminary line presupposes, the preliminary line should show moderately long tangents connected by small angles whose sum is a minimum.

Having completed his notes on the preliminary map and profile, on the day preceding the one on which the line party starts the located line, the chief of party explains the problem in camp that night to the assistant. A line is drawn on the map representing where the located line shall be, and showing the "tying in" with the preliminary line about once each day's work. The profile is dotted in. Next morning the assistant takes the map and profile with him to the field and starts locating. The chief of party resumes reconnaissance work beyond the first secondary controlling point which the preliminary work has now reached, and carries the reconnaissance to the next secondary controlling point, before the party locates to the first secondary controlling point already mentioned. The camp remains where it is until the location now on paper is run in. Moving camp costs money and is dangerous in winter in northern latitudes. Failure of the chief of party to see obstacles to line far enough ahead will cause backing up and loss of money. He must ride far out on reconnaissance. He must have experience, endurance and the best of horses to ride. This general field method is the cheapest for much of our ordinary country.

We have said that the assistant locates the line studied by the chief of party on the ground and drawn in on the preliminary map, but he must be given some discretionary power. A machine is never an assistant, and the method is too rapid to make it safe to assume that the study of the line and the ground is exhaustive. Some consider the field party a machine and do good work with it, but the writer feels that he needs the best man obtainable for an assistant, and has always listened to the opinion of any man of the party. The railroad company pays for all there is of knowledge possessed by the entire party. The more you lean on all your men the more you will distance your competitors.

The detail line work of each instrument and man on location does not differ materially from that described in Chapter IV. for the preliminary line. It is a mistake to do inaccurate work on preliminary and try to make amends for it by special care on location. Transit points and bench marks and chaining must be as accurate on preliminary as on location, so as to check location instrumental work. On location, stakes must be driven at each station and must be more carefully lined by the transit. The rod readings at those stakes must be more carefully taken on location. Starting the transit line on location you use the same initial point and back sight as on preliminary. You run in the transit line as shown on the map for located line until you are one "set up" of the transit back of the first "tying-in point."[1] Then drop the located line and go ahead with the transit and set up on the nearest "hub" of the preliminary. Line in two hubs, one on each side of where the preliminary line will cross the located line and a few feet apart. Then return to the located line and line in an intersection. Measure this "angle of intersection" and both plusses—marking angles of intersection and the equalization station numbers on the map. You do this so as to keep the located line on the "ground" which the preliminary line occupies, and at just the distance from it directed by the chief of party the day before. You may "tie in" every mile. You should "tie in" once a day, at least. If you do not use this plan, you must compute your location alinement instead of platting it. Platting without "tying-in" is not close enough.

CURVES.

The practice in curves followed by engineers is not uniform. The old way was to judge when to start and judge the degree of curve. As you ran around the curve, you stopped where the tangent direction appeared to lead right. If the transit contradicted the eye, the curve was run ahead or backed up to suit. Such practice is slow, costly and not advisable. Some engineers do not run tangents to intersection in field but plat and compute the angle. This is probably the best plan when the office force is adequate, but cannot be done when the field men do the office work at night. Of course it must be done in rough country, where intersecting the tangents in the field costs too much time.

For the case under consideration, where country requires but one preliminary line, it is usually most economical to run the back tangent to the point of intersection and from that P. I. turn off the desired angle or turn to the desired object ahead. Having the angle of intersection, and knowing the degree of curve from the map, compute the tangent lengths and the length of curve. The transitman does this computing. The assistant checks him. If easement curves are used, they are here provided for. Instead of com-

[1]The point where the located line meets or intersects the preliminary line.

puting lengths of tangents and of curve it is economical to use a field book that gives these lengths at once from a table. Next chain the tangent length forward from the P.I., and put in the P.T.[1] The angle must be measured twice for accuracy and it is better to read the angle and the double angle. With the transit still at the P. I. go back and plus in the P. C. Now place the transit at the P. C. and run in the curve. Use shorter sights than on a tangent especially in cuts or in heavy clearing. The computed station for the P. I. is marked on the witness stake after the chained distance around the curve has been called out by the rear chainman and the error in chaining noted by the transitman.

How closely should the chained and computed length of curve check? Engineers will differ. It is the writer's practice not to re-chain when the check was to the nearest foot on a curve 1,500 ft. long. The nearest unit is close enough. The error is dropped at the P. T. Many chiefs of party insist on closer work in chaining.

Errors in "plussing" are most common—a rear chainman's error. When starting on the P. T. to run forward on the front tangent always take the back sight on the P. I. Never turn a tangent to a circle from a vernier reading, when the P. I. has been located in the field.

TOPOGRAPHY.

The topography on location is for record. Plusses to land lines, their bearings, and a transit connection of the center line once in each township must be made. Owners' names should be taken when convenient. Outcrop of rock, probable depth to rock and the nature of that rock are important. Plusses where clearing or grubbing is entered or left, must be shown. Direction of streams with reference to center line is important. Class of foundation of bridges, whether piling can be driven and how deep, with high water marks of streams are important. Clear opening at bridges required must be noted. Every structure, bridge, road crossing, cattle guard, culvert pipe, etc., must be marked with its location. Ditches, where they avoid openings, must be noted so as to be considered that night in the light of what the profile shows. In short, the topography on the right of way must be minutely and fully taken, and all information gained necessary to condemn right of way and let contracts for construction. Enough topography must be taken outside the right of way to map the topography of the route. Engineers will see at once that an assistant must be more than a topographer to do all this. The rear chainman notes the plusses for the assistant, and checks the stake marking. Repeating or omitting numbers on stakes should never be allowed. Avoid

[1] P. I. means "point of intersection" of two tangents; P. C. means "point of curve," or beginning of curve; and P. T. means "point of tangency," or end of curve.

equalization numbers[1] if possible. Such things create expense until the line is rechained to make distances more easily obtained for operating purposes.

The levels on location should check on preliminary bench marks. The limit of error used differs with chiefs of party. The writer's custom was to consider the nearest tenth of a foot a check when the B. M.'s were 2,500 ft. apart and the station heights are read to tenths, while the turning points were read to hundredths of a foot. The level instruments were not very sensitive in bubble, purposely, for other reasons. Closer leveling can be done. But fast work and high winds require that a levelman be quite capable to do even this. Station elevations must be carefully taken. Plusses to changes in slope between stations must be taken whenever needed. Plusses to all tops of banks, channels, etc., must be particularly taken. Bench marks must be put in more frequently than on preliminary, certainly each 2,500 ft., and these benches must be chosen to be as available in construction as possible. Hub and stake benches are best, and should be placed about 25 paces away from the center line opposite some full station and near the grade elevation. Outcrops of rock must be noted in kind, in plus and in offset. Waterways must be also located and these rock and high water notes placed on the profile. Plusses to where clearing is entered or left are taken by the levelman to use if the assistant omits them. It is undoubtedly wise to use a slope level, and take notes on all lateral slopes that materially affect quantities. Where work is cross sectioned, the side slopes are not so important. The check level is a second level taking turning points and bench marks only for the purpose of avoiding cumulative errors in levels. The preliminary levels check the location levels where the lines are close enough to tie in. But a check level should never be used because the levelman doing the full work is unreliable.

PLATTING.

At the close of the first day's work of running in the located line in the field, the map and profile of the located line are started. The transitman or draftsman plats the map, the assistant checking the computations. A good working method is to plat the map on sheets of good manila paper, choosing the direction of the magnetic meridian so as to use the full length of the sheet. To plat on a roll is unhandy, and changes of direction make offsetting frequent. Plat by tangent deflections, to a scale not smaller than one inch to 1,000 ft. and ordinarily not larger than 1 in. to 400 ft. The latter makes the map the same scale as the horizontal scale of the profile, and is very convenient for the chief of party. Sweep in the circular curves with the compass, and use a special templet for your easement

[1]Equalization numbers occur where a stake must have one number on the back to correspond with the system of numbers back of it and another number on the front side to correspond with the system of numbers in front of it. A gap or a lap in stations takes place at that stake.

curves. Ink in location alinement, with bearings, stations at all changes of direction, and mark each tenth station. The transitman's work on the map is done. The assistant or draftsman now pencils in all of his topography and gets from the levelman any supplementary notes he has, if needed. He plats land lines and gives names of owners. He confers with the chief of party about topography far from center line but needed to make an intelligible topographic map. The chief of party examines the map to see that it is complete and as full as necessary. The profile is usually of greater importance to him, however.

The profile is platted by the levelman. He must previously check his subtraction made in the field for elevation of stations and plusses, the rodman calling off the notes. Nowadays the profile paper used is 1 in. to 20 ft. in vertical scale for located line. This plate "A" of the manufacturers is quite exclusively in use. It is the best for located line, but the writer began with the plate "B," that is 1 in. to 30 ft. in vertical scale and uses no other, for the eye gets trained to a scale and it costs to educate it again. For the field the smaller scale is more portable. The large scale is customary now and should be used. The platting of a location profile differs from that of the preliminary only in having more plusses and every station where the preliminary may have but alternate stations. Every 10th station must be marked at the top of the profile, and every 50 ft. of elevation must be marked at each 50th station. Names of streams must be written in. Location and elevation of high water marks and rock outcrops must be given. The P. C., degree of curvature and P. T., together with the easement curves are marked at their proper station and plus on the profile. The "section posts" are placed on the profile, the first four sections being 53 stations each in length and the fifth 52 stations long, so that five sections equal five miles. This completes the levelman's work for the day. The profile now goes to the chief of party to lay the grade line and complete the profile.

Sometimes it is necessary where construction follows closely on location to send records of each ten or twenty-five miles located line, as fast as completed, to the general office. To do this, as the rodman calls off the notes for the levelman to plat, let the chief of party plat the profile to be kept in camp, the levelman plat the one to be sent in, and the draftsman copy into a book the stations, plusses and elevations. This is done while the assistant is putting the topography on the map after the transitman has platted the center line.

The general considerations which should guide the chief of party in laying grade line on the profile, have been stated in Chap. IV. Certain things must be noticed or provided for on a location profile which do not exist on preliminaries.

On location the gradients must be kept in as few decimal places as possible. Otherwise you are making work for construction men

in computing grade heights for stations and in running them in. Furthermore, you should change rates of grade at full stations. Lastly, you should change the rate of grade at elevations expressed in feet and tenths of a foot. If you can not avoid these three things, as a rule, you are not expert at laying grade lines: First, try to use rates of grades in full tenths of a foot, although you may use a half tenth; Second, try to change rates of grade at full stations, although you may change rate of grade at plus 50 ft.; Third, try to change rate of gradient at a grade elevation of exact feet, although you may change at an elevation of exact tenths of a foot. Observing these rules means more work in laying the grades but saves time and money for the company.

Equating for curvature must be done and this must include equating for the easement curve. We have considered equating for circular curves in Chap. VIII. For the easement follow this rule in equating: Equate the amount in gradient which the total curvature in that one easement calls for, at the rate at which you are equating for the number of degrees in that easement. This gives the total equating for one easement. Now distribute that amount uniformly over the easement. In other words, equate as though the easement did not taper in sharpening of curvature, and for the actual degree of curvature that easement contains. A grade line over any curve equated for curvature is a broken line. It is troublesome to lay it. The chief of party uses fine black silk thread and sharp pins in laying such a grade line. As he equates for curvature he breaks grade oftener on maximum gradient. It is better to work ahead some distance, leaving the pins in place to mark the grade changes before drawing in any grade lines. High water marks and outcrops of rock are in this way less apt to be overlooked. You make better progress by stopping your work some distance back when you near a maximum grade, and then go ahead and lay the maximum grade first, starting it at a full station and exact foot of elevation. Take care not to overlook any detail in computation while laying a maximum grade and try to use some level grade at each end of it. Then the only betterment in grade laying, on that broken line which is the equated maximum grade line, is to raise or lower it uniformly throughout its length. With level grades at each end of the maximum, the shifting is but local. It is fair to presume that later you may see a mistake. Besides, grade lines laid at night need looking over in daylight, for in spite of care shadow may be taken for the silk thread. The minor gradients are supposed to be easier to lay properly; but since the revelations of the locomotive engineer have led to the use of a virtual profile, the minor gradient has many pitfalls. A level gradient has no essential virtue. Cuts will not drain along it. Changes of a very few tenths per station are not objectionable at all, if the "sign"[1] of the gradient is

[1]The + sign denotes rising grade in the direction that the line is run: the — sign denotes a falling grade.

not changed. Undulating minor gradients well rounded off by vertical curves so as not to break couplings are less detrimental to a road than we formerly believed. We have no doubt wasted money in the past in avoiding them. We have seen by virtual profile that summits of less rise than can be overcome by the *vis viva* of the train do not increase the demand upon the locomotive. Therefore such summits do not increase cost of transportation save in minor ways; they somewhat increase maintenance, but do not at all limit the traffic capacity. We must remember, in laying grades that *vis viva* does not exist at stops and is not fully attained for some distance each way from a stop. At summits of more than 25 ft. there is no *vis viva* available. It follows, therefore, that we should, within these limits just noted "chop" grade lines and save cubic yards of grading on minor grades and short maximum grades, and do all economy will allow to shorten or flatten grades on minor gradients up hills over 25 ft., and especially on maximum gradients on hills considerably above 25 ft. in total rise.

VERTICAL CURVES.

Vertical curves must be used on construction to connect at least all grade lines which would otherwise break couplings. These are especially needed at the bottom of a hill. Having decided upon the length of vertical curve you will use for your road, unless your instructions cover that point, find out how far the vertex is from the center of the vertical curve. Keep in mind these particular distances: first, when two maximums meet; and second when a maximum meets a level grade. The other cases will approximate to these two in amount. Vertical curves, on the whole, increase the cubic yards of grading and materially increase the work at the intersection of grade lines. Finally, in laying a grade line on a location profile, we must bear in mind:

First—Cost of transportation on the line after it is built;
Second—Cost of maintaining the line;
Third—Cost of construction.

Having laid the grade line on the days work, the bridging must be placed upon the profile. The chief of party confers with the assistant who reads from his notes where small openings are needed and the amount of "clear openings," i. e., distance between foots of slope at larger openings. In case of any doubt, the level man is asked for his notes at that bridge. The clear openings, plus three times the fill gives the distance between tops of opposite banks. Add to this the amounts that the "bank sills"[1] set back from the top of the slope, and we have the length of structure. Take that length next above which is a multiple of the length of stringer

[1] A "bank sill" is the timber upon which the ends of first stringers of a trestle rest; the other ends of the stringers rest upon the caps of the trestle bents.

of the bridge plans and mark it, e. g., 70 ft. Pile Bridge, or Trestle Bridge if piles cannot be driven. This is the ordinary case. Span bridges require more attention, and often require a further examination as the foundations have much to do with span lengths. Ditching one drainage waterway to another, and making one opening serve for two is generally bad railroad practice. It causes washouts or it lets water on the track and cuts out under the ties. Water will not change its course 90° without finally giving trouble. Ditches will stop up, and these surface ditches are the last ones to which section men give attention. This applies to small drainages. With larger streams it is less dangerous in point of frequency but more disastrous to change water courses. Where nature uses a waterway, it is the best plan to put a bridge and not carry a volume of water along the embankment. All minor structures must be put in where the law directs, taking advantage as given by the topography, and making the larger structures do duty for smaller ones as well.

Dot a line of demarkation in the cuts between the different classes of material. Notes of outcrops aid this, but the demarkation must be estimated from what the assistant and chief of party have seen and their general knowledge of the country. If more than the usual width of right of way is required for borrow pits or spoil banks, so note it on the profile as well as where clearing commences and ends. The profile is complete save additional notes of the chief of party who may find it best to look at the located line next day.

The other profile, if made for the general office, has the grades and all notes placed on it. The map is traced, and the alinement and grade and bridge notes are all copied into the record note book which the draftsman made as the two profiles were being platted. At the end of ten miles, or any other length of section, the tracing, copy of profile and complete record are sent in to the general office. The records here described are sufficient for the legal department to condemn or purchase right of way, for the engineering department to estimate cost of construction and make out complete bills of material. This is done without any question being necessary to be asked of the locating party or anyone being sent out to get other information. The locating party has, therefore, performed its business function.

Before closing this topic, it seems best to say that accomplishing this requires certain understanding between the chief of party and the chief engineer. For example, length of piling is not stated, but it can be understood that where pilling will penetrate a depth other than say 10 ft. that fact must be marked on the profile. At span bridges, over water of some depth, soundings must be shown and a cross section to large scale shown. If rock exists or is suspected, a pipe in sections must be driven down to it. Then have it understood that unless drift or other cause prevents, you have

made the length of span such that a span equals in cost a pier of permanent work. Customs of old roads aid much, and deviations from the expected are all you need to note for estimate and purchase of material.

The first day's field and office work on location being completed, the field party may continue location the next morning if there is enough line to be located for a day's work still remaining on the preliminary map. Otherwise the party returns to running preliminary line. It is best to run all the preliminary intended from one camp before starting the location work to be done from that camp. The chief of party should, as an added precaution, walk over the located line with the map and profile of that line in his hands, and examine grade line heights, rock outcrops, high water marks and location, character and class of openings. He notes where rock, swamp, etc., makes more right of way needed and in general checks the work and makes sure that he has full and correct information on his map and profile for an estimate of cost, condemnation of right of way, bill of materials, and the letting of the contracts—with no necessity whatever for the chief engineer or anyone else to look at that line until contracts are let, right of way steps taken and material bought.

LOCATION FROM SEVERAL PRELIMINARIES.

We consider, finally, the case in railroad location where several preliminaries are required. This is the general case. In our study of the case where one preliminary was necessary, we have described much of the field work and treated many of the questions that bear upon our problem. The difficult question of comparison of preliminaries still remains. We shall consider this case in the usual order of events as it would occur to a locating party. Comparisons of preliminaries as to relative value of each are best made through capitalization of each preliminary. It is at once seen that many questions arise. Some are capable of solution by a civil engineer, some by a mechanical engineer, some by the traffic and some by the transportation department.

COST OF TRANSPORTATION.

The usual basis of comparison of costs of transportation of different lines or of different parts of the same line, is the cost of the train-mile. The cost of the ton-mile instead of the train-mile seems a better criterion. At present there are too few data to use the ton-mile system, although it now seems clear that ton-miles will replace train-miles as the unit. The ton-mile is the revenue standard, why not use it as the expense standard? By the cost of train-mile is meant the cost of hauling the average train for the average mile. While this cost varies with different roads, yet it offers the best basis of comparison. The usual cost of a train-mile in the United States has been about $1, distributed as shown in the accompanying table:

Obviously it should be known for the road for which the location is being made. It is not a factor of density of population or of efficient management. Gradients, engine weights, class of traffic—all modify it. As it is considered to be exactly $1, the percentages entered in the table represent also cents per train mile.

Approximate Estimate of the Details of Operating Expenses for an average American Road.[1]

Train Expenses. 47 0 p. c.	Engines. 18.0 p. c.	*Road engines.* 14.4 p. c.	Fuel	7.6 p. c.
			Water	0.4 "
			Oil and waste	.0 8 "
			Repairs, engines	5.6 "
		Switching engines		3.6 p. c.
	Train Wages and Supplies. 17.0 p. c.	Switching-engine wages		1.6 "
		Train wages and supplies. 15.4 p.c.	Engine wages	6.4 p. c.
			Car wages	8.5 "
			Car supplies	0.5 "
	Cars. 12.0 p. c.	Repairs and renewals		10.0 p. c.
		Mileage (a practical equivalent for repairs)		2.0 "
Maintenance of Way. 23.0 p. c.	Track between Stations. 8.0 p. c.	Renewals of rails		2.0 p. c.
		Adjusting track		6.0 "
	Road-bed, 7.0 p. c.	Renewing ties		3.0 p. c.
		Earthwork, ballasting, etc.		4.0 "
	Yards and Structures. 8.0 p. c.	Switches, frogs, and sidings		2.5 p. c.
		Bridges and masonry		3.5 "
		Station and other buildings		2.0 "
Total "Line" or Transportation Expenses				70.0 p. c.
Station, Terminal and General Expenses and Taxes				30.0 "
Total Operating Expenses				100.0 p. c.

The surplus, or profits, or net earnings (all having the same meaning) is that remainder left when from the gross earnings we deduct both the operating expense and the fixed charges. Out of this surplus, profits or net earnings, must come the dividend on stock, if any, and such reserve funds as are set aside to meet bonds when due. Operating expenses consist of train expenses, maintenance of way expenses (these two together being called transportation expenses) and a third class of expenses which are termed administration expenses consisting of all station expenses, general

[1] Reprinted from p. 179, Wellington's "Economic Theory of Railway Location."

office expenses and taxes. Fixed charges are interest on bonds, guarantees of interest on stock or bonds and rentals.

In general, it may be said that for the average of American railroads, the operating expenses are about two-thirds, or 66% of the gross earnings. No such general proportion is ever satisfactory, but some ratio is needed as an aid to the perception. Of these operating expenses we may assume, with reasonable accuracy for the general case, that 45% is for train expenses, 25% for maintenance of way and 30% for administration expenses.

The transportation expenses consist of train expenses and maintenance of way expenses. It will be found that these items resolve themselves into two classes: (1) those of time, and (2) those of resistance. The items which incur expense through cost of time are: (1) wages of employees, (2) evaporation due to cooling of boilers and (3) deterioration of material through age. The items which incur expense through cost of resistance are: (1) fuel, (2) water, (3) engine and car supplies and repairs made necessary in actually moving the traffic, (4) repairs of engines, cars, track and structures due to wear.

In considering the advisability of running a preliminary along a certain route, it is too much to expect a locating engineer to consider all the items of transportation in their various percentages and amounts. It has been customary to use the equated length of line as the yardstick by which to measure the value of each preliminary. To do this, all items of transportation expenses which do not vary directly with the length of the line are converted into length. For example, a certain number of degrees of curvature is found to offer the same resistance to traffic and cost as much to operate as a mile of straight level track. We thus "equate" this curvature and add to the measured length of the line a certain other length whose resistance to trains equals the resistance offered to trains by all the curvature.

We must bear in mind that we may also equate gradients on each curve for the amount of curvature. This is equating curvature into rise and fall instead of into distance. It is usually done on a located line but must be done on a preliminary and then shows by a jump in grade elevation rather than in change in rate of grade.

In our study of the choice between several preliminaries, let us assume the simplest case. Suppose that the survey requires but one preliminary for most of the way, but that at some one place for a few miles two preliminaries are required. The camp should always be located by preference at the difficult parts of the line. Assume that it is so located, that the located line is completed to within six miles of camp and that the first preliminary has been run five miles beyond camp on the route which gives most promise of a satisfactory line. But the chief of party desires to improve that line because it is too circuitous, or has too heavy grad-

ing, or misses a town. He has found a different route for that five miles. It also has its drawbacks. Plat the second preliminary line on the map over the first preliminary, and its profile over that of the first profile. The tieing in of the plat checks the field work. The levels have a field check. The grades are laid and drawn in. Bridges, etc., are put on with full care. Vertical offsets are made in the grade line to equate for the angles turned. This suffices for the profile and estimate of grading, but does not suffice in estimating rise and fall of line.

We are now ready to begin the office work of the field party in comparing these two preliminaries for this short distance, so as to determine which is the better for the company to locate and build. First, we must know what it costs our railroad company to hire money. Obviously if the money can be hired at 3%, i. e., its 3% bonds sell at par, we can economically spend more money to save $100 in annual wages or fuel than if money is worth 6%. Second, we must estimate the volume, direction and kind of traffic our line will have, irrespective of any it acquires on this five miles, the route of which is now in question. It is quite impossible to predict traffic for more than five years in advance, but it may be known in a general way.

In comparing two preliminaries one may show less curvature, the other less grade, while the two are equal in length. We might capitalize distance, grade, etc., although this is laborious and often unnecessary. Since increased demand upon the locomotive is the channel through which traffic taxes operating expenses usually, let us use that increased demand in lbs. per ton as a means to convert one train resistance to another. It not infrequently happens, in practice that the comparison of equated length of lines is all that is needed to decide which one of our two preliminaries to adopt, without capitalizing them.

We do not consider maximum grade resistance, as such. for this short preliminary for in no case would a change of maximum grade be considered in minor changes of route. All grades are considered together, therefore. Nor do we consider limiting curvature resistance for a curve is never put in on a minor change of route which has so short a radius that it limits the engine capacity. Such a curve would have precisely the same effect as increasing the maximum grade for a short distance. Minor changes need not be considered in the light of maximum rates of resistance, for in practice they never so occur.

It is not at all likely that any change in train velocity will ensue from our choice of route. Nor is it likely that added train stops will be necessary. We therefore do not consider velocity or starting resistances. Should a special case arise where either of these resistances need to be taken into account in a minor change, data for their use can be found in the consideration of the general case immediately following this special case.

EQUATING GRADES.

We have seen that the grade to consider is the virtual profile grade. We have seen that without exceeding usual freight train speeds a train will pass down and up in a 25 ft. sag with only the usual demand on the locomotives of 7 lbs. per ton, i. e., such sags may be operated by the same motive power in the same time and at the same cost as so much straight, level track. Instead of platting the virtual profile for the slowest and fastest trains each way, it will answer our present purpose if we cut off the bottom 25 ft. of each sag and consider the sag non-existent. This gives a level grade over them, and to a level grade we are converting all grades. We need now only consider the remaining hills. We have then no *vis viva* of trains. Our velocity head is 3.55 ft. above the top of rail at the bottom of the remainder of the hills, and we have there an engine speed of but ten miles an hour—all needed for contingencies. All remaining grades cause a direct demand on the locomotive. To compute each is laborious and unnecessary. The 7 lbs. resistance per ton on straight, level track is our yard stick. How shall we convert these resistances of the various grades of the profile to the resistance of straight, level track? Now, 7 lbs. is 0.0035 of a ton of 2,000 lbs. Therefore, straight, level track has the same grade resistance as a 0.35% grade. Therefore 100 ft. of 0.35% grade has the added resistance of 100 ft. of straight, level track; and 100 ft. of 0.70% grade has the added resistance of 200 ft. By successive multiples of 0.035 we see, disregarding small decimals, that

Added resistance,	100′ of	0.35%	grade	=	100′	straight	level	track.
" "	100′ "	0.70%	"	=	200′	"	"	"
" "	100′ "	1.00%	"	=	300′	"	"	"
" "	100′ "	1.40%	"	=	400′	"	"	"
" "	100′ "	1.75%	"	=	500′	"	"	"

Now go over the profile of our preliminary, counting the number of stations of grades not level and not above 0.35%. Add this length to the measured length of the preliminary. Count the number of stations having a gradient greater than 0.35% and not over 0.70%. Multiply this number by 2 and add it to the measured distance. So count and compute each group of gradients and the total of these equivalent lengths together with the measured length of preliminary will give the equated length of line as viewed from the standpoint of train resistance, and demand upon the locomotive.

We have not considered direction of traffic. For this minor change we can usually disregard it in equating, and consider it equal in tonnage in each direction. If one end of our line was at the same elevation as the other, unequal traffic would have no effect. If the traffic is very unequal in tonnage, consider only the gradients against the heavier traffic. Now we have considered the resistance to traffic due to grade in both directions. In one direction the grade causes resistance while in the other direction the

grade causes acceleration. This is obviously wrong, for while the acceleration is of course used up in the bottom 25′ of the sag, still the minus grade offers no added resistance. It is therefore a level grade in resistance. With traffic equal in each direction, and with the ends of the preliminary line at the same elevation, we may find our equating other resistance into distance resistance give an added length double what it should. Traffic is seldom the same in tonnage or in earning power in each direction. A topographer knows that an obstacle lies between two points having the same elevation. It may be wise to reduce the added length for equating 50% for the above reasons. It will be found that 25% is a more common case. But, as we are equating for obstacles, we must keep on the safe side for capital, and unless it is clearly excessive, it is usually wise to take the length as equated by the foregoing process with no percentage for unequal traffic or for the fact that traffic has some grades in its favor. It should be clear that there is a limit beyond which this study of the general case cannot go. Each case is a distinct problem to be studied by itself.

EQUATING CURVATURE.

We must now consider curvature as a resistance to traffic and equate it to length. We have seen that one degree of curvature increases the pull on the drawbar behind the tender ½ lb. per ton. This is regardless of the degree of curvature at any point. Add together the intersection angles for the line. Since degree of curvature makes no difference[1] in the resistance, we may assume that the curvature is all 1°. The total number of degrees of curvature therefore equals the length in stations of 100 ft. of the curvature, from the standpoint of resistance. Since curvature offers a resistance of ½ lb. per ton, and distance offers a resistance of 7 lbs. per ton, then 14° of curvature (1,400 ft. of 1° curve) equals in resistance 100 ft. of distance. Dividing the total number of degrees of curvature by 14 we have the equated curve length of line in stations of 100 ft.

MAJOR CHANGES.

Having considered the minor changes in route, we must study the great changes. These last changes involve all the questions of the minor changes and others beside. By a great change we usually mean a considerable portion or all of an operating division of, say, 125 miles. More, or heavier engines, assistant engines at given points, new local traffic, considerable losses or gains in distance, wide variations in cost of construction are the new important questions. What has been studied in minor changes of route apply here as well but with a varying force. The laws are the same, but they may be inoperative in minor changes while of sweeping force in greater changes of route. In general, these greater changes are best studied each by itself. To use train-mile cost is scarcely

[1]The writer understands this conclusion of Mr. Wellington's is disputed in the discussion of the paper referred to in a foot note on p. 207.

admissible. Moreover, we should look closely to traffic to be gained or lost at local points. The effect on through traffic of great changes is often surprising. Following the order of resistance items as in the minor changes just considered, it is necessary now to go outside the choice of routes to be weighed. We now have the operating division to consider, as a whole, or perhaps the entire line of survey.

VIRTUAL PROFILE.

Taking up our resistances in their order, as before, we consider first the Minor Gradients. For the minor change we assumed the bottom 25 ft. taken off all hills and that the rate of profile gradient fixed the demand on the locomotive for the remainder of the climb. This is too crude for great differences in route. We may disregard for a train all sags which have less velocity head than the allowable maximum head of that train[1] except where stops, sharp curvature, etc., make it unsafe for the train to run at its otherwise maximum speed. It will be seen that since a freight train running at only 28.4 miles per hour speed has 25 ft. plus 3.55 ft. of velocity head, i. e., we may consider the grade elevated 25 ft. above the profile grade whenever the train can attain full speed and still have the 3.55 ft. velocity head to spare. This 3.55 ft. velocity is equivalent to 10 miles per hour, which is the lowest economic speed for trains. Therefore, when the grades promise to tax the locomotive, construct the virtual profile grade line. Laying off these velocity head distances where needed, and as attainable, draw a new grade line for the virtual profile to the top of the controlling hill, but to a point 3.55 ft. above the profile grade line. This is to insure 10 miles per hour speed at the summit—for economy and contingencies. Calculate the rate of ascent of this virtual profile grade line. This new rate is the gradient which fixes the rate of demand upon the locomotive. It is not necessary to construct the virtual profile throughout the length of the line, but only at the places where needed velocity can be had to materially help the locomotive. In a word, you draw the virtual profile grade line and compute the virtual gradient, wherever the locomotive engineer needs to and can "take a run" at a hill to help himself over it. We have said that sags dropping below the trend of grades by a less amount than the velocity head of the maximum speed of the train may be disregarded. On long maximum grades, the locomotive engineer finds his speed dropped to 10 miles per hour long before he reaches the summit, and on such hills the profile gradient is the ruling one. On such long maximums the virtual profile coincides with the profile of the line. Sharp curvature which makes it necessary to reduce speed to, say, 15 miles per hour puts a sag in a virtual grade line. A stop loses all velocity head. The question as to how far the bottom of a hill

[1]See Table 118. "Economic Theory of Railway Location."

must be away from a stop on a level grade before the full benefit of velocity head is available, is a question of local conditions. Heavy trains require more distance to get up speed. Some engines are slower than others in "getting away" from a stop. A half mile is not an unusual distance from the stop to the foot of the hill. It is often best to plot the virtual profile at stops. If we only knew where all future stops would be located, we could save much waste of money.

Having carefully drawn the virtual profile grade, and marked on it the virtual gradients, count the stations of each rate of grade and convert each to distance, similar to the method used in minor changes, or you may group the gradient precisely as before. This is laborious but accurate. Of course all gradients are included, whether maximum or minor gradients.

If it be preferred, the cost per train-mile may be used.[1]

MAXIMUM GRADES.

When we have calculated the effect of maximum and minor gradients in their demand on the locomotive, as we have just done, we have not touched the real cost or significance of maximum grades. It is questionable whether it be safe to use the general cost of the train-mile ($1 or a slightly different value) when comparing a preliminary of say, 1.00% maximum gradient with another preliminary of say, 1.25% maximum gradient. If it be the same train, the cost must increase with the gradient. Obviously, the cost per ton-mile is more. If the trains vary in length or in weight to correspond with the variation in rate of maximum gradient, then the cost of the train-mile is no standard by which to compare these gradients for the train is a variable quantity in length, weight and "earning power." Where preliminaries differ in rates of maximum gradient, it is likely that the choice of maximum gradient will overshadow all questions of curvature or rise and fall. Where the road will do business enough to pay a reasonable rate of interest on the cost of line of lower maximum gradient, all preliminaries on higher maximum gradients may safely be set aside without computation or comparison. The inherent effect of the maximum gradient, as such, when considered in the light of considerable traffic, controls the choice of preliminaries. A chief of party will find that, where one hill of, say, 5 miles is the only place on an operating division needing a 1.25% gradient all the rest of the way requiring 1.00% gradient, the cost of construction for that 5 miles can be enormously increased and still justify the 1.00% gradient for the operating division. The writer has learned by experience that where there was a possibility of reducing the rate of maximum gradient, all other questions of resistance should be held in abeyance.

There are three ways of providing for increased rate in maximum gradients:

[1]See "Economic Theory of Railway Location," Table 124, for cost per train-mile of 26.4 ft. of rise and fall of various kinds.

First, by using Assistant Engines. This plan is used where the higher maximum gradient is short. Assistant Engines are termed "Pushers," because it was formerly the custom to have them push the train from behind. This enabled them to uncouple and get away from the train without the train or "road" engine being compelled to stop and so lose headway. Switch engines are often used in this service. The train unit remains the same when assistant engines are employed. This is the method of bunched grades.

Second, by increasing the number of trains. This plan is commonly used where the higher maximum is used for a longer distance, but not for an entire operating division. Doubling the number of trains is the favorite method, and is always done when the change in rate of maximum gradient is enough to warrant cutting trains in two. Such adjustment of "grade breaks' to motive power is a question too little considered by locating engineers. This second method is where "hill engines" are employed. The "hill engine" has sufficient tractive power to take over the higher maximum gradient all of the train the road engine is obliged to "set out" because of change of maximum. This hill engine may run as a "second section" and turns over to the road engine this overplus of cars at a point beyond this higher maximum gradient. Trains are not "broken up."[1]

Third, by increasing the weight of the engine. This plan is used where the higher maximum is used over all, or nearly all, of an operating division. Changes in rates of maximum grades should, if possible, occur at ends of operating division.

It may be urged that the length of the operating division was not a unit in the formation of the earth's crust. Nevertheless there are many breaks in maximum grades on profiles that are as useless as they are ill-placed. To increase the weight of the engine so as to haul the same train which lighter engines haul on adjacent divisions is the economic method of arranging a change in a rate of maximum gradient. Mr. Wellington considers that doubling the number of trains costs 49.5 cts. per train-mile, while doubling the weight of engines to haul the same train costs but 14.1 cts. per train-mile. Doubling the weight of train might be, in practice, dangerous to draw gear. Increasing the weight of engines ¼ or even ½ would not be dangerous, and that is the usual range of changes of maximum. These amounts correspond to breaks for a grade of 0.80% to 1.00% or 1.25%. Or they agree with breaks from 1.00% to 1.25% or 1.50%. These are common changes in rates of maximum gradient.

Each of the three plans we use gives a different cost. Each is adapted to its own circumstances. Therefore, we must choose our method, whether by (1) assistant engines, (2) more trains, or (3) heavier engines, and compute the cost for the method adopted at that locality.

[1]See "Economic Theory of Railway Location," Table 176.

Assistant Engines.

An assistant engine costs per ton per mile, we may assume, the same as any other engine, during actual work. Its interest charge is similar. It must return down the grade. It will not be constantly in use. The wages of the crew are a per diem charge. The fuel and other supplies are not taxed while returning down grade or while standing between trips except as are other idle engines. The losses through radiation are larger in cold weather. To allow a percentage high enough for banked fires is not sufficient for delayed trains and extras require a "pusher" to be "kept hot" the greater part of the time. Ten per cent. might be a sufficient fuel allowance. It is best to consult your motive power department for such data, but in the absence of it, if the business keep the assistant engine busy less than half of the time, add to cost per ton per mile one-third the actual cost of hauling for losses due to idleness, and if the engine be busy half of the time or more, and one-fourth to the actual cost of hauling. Actual cost for your case is better but these approximations will serve in emergencies.

The cost of increasing the number of trains, as we have seen, may be allied to the use of assistant engines, particularly if cars are set out at intermediate points on an operating division, and there made up into additional trains which run to the end of the division. The usual case of increasing the number of trains is where the number of trains is changed over the whole division. The trains may be doubled in number or two trains made up into three, etc. In the former case, viz., increasing the number of trains over a part of the operating division, consider the extra cost to be precisely as for assistant engines which do not stand waiting for trains. In the second case, viz., increasing the number of trains over the whole division, consider the same train-mile cost, but at the reduced tonnage due to increased grade. For example: If one preliminary line on one operating division requires two engines and trains to haul the daily traffic, and the other preliminary line compared with it requires three similar engines with trains to haul the same tonnage then the increased cost for train service is 50%. One gradient may be 1.00% and the other 1.50%—in this case. The increase in train cost is directly as the increase in gradient rate—other resistances being equal. There are two things a locating engineer cannot modify in their consequences, one is the virtual grade line and the other is a maximum grade having length enough to make its rate felt. We must take no liberties with either. It may seem that certain items of maintenance of way, as rail wear, for example will vary as the tonnage, and that as the tonnage is the same whichever maximum is used, it is wrong to add 50% to the item when we propose to use the higher maximum. But do rails wear no more on a hill than on a level? May it not be true that rails wear here as the gradient rather than as the tonnage?

Heavier Engines.

The cost of increasing the weight of the engines is finally to be considered. This plan leaves the train undisturbed. Train weight is the same. Of course the number of trains is the same for the same tonnage, but engine weight must be increased to correspond with the increase in rate of maximum grade. Wherever practicable, this method is preferable from the standpoint of operation. We increase the tractive power just as demanded by the higher grade. We burn more coal on our larger grate and evaporate more water from our larger heating surface all in proportion to demand. This is all unavoidable. But by this plan we have no increase of pay roll (unless a slight increase be paid men on heavier trains) and we have no added losses due to more trains or more time waiting for them. As we have stated, Mr. Wellington shows that doubling the number of trains increases the cost per train-mile 49.5 cts. This applies to assistant engines over mileage as well as added cost of delays. But he shows us that by doubling the weight of the engines to haul the same train, it costs but 14.1 cts. more per train-mile.

Adapting Grades to Engines.

The writer wishes to make himself clear in this matter of arrangement of rates of maximum grades. He believes that if there be four operating divisions of a road and four different weights or types of freight engines on the road the locating engineer should try to have each of the four divisions throughout their several lengths exactly tax some type of engine of the road. He should aim, therefore, to haul the same weight and length of trains over the entire four divisions without setting out or picking up cars. Suppose the train has forty loads of 20 tons each. If the first division have the lightest grade, suppose the smallest engine (American) can just haul it at desired speed. Suppose the next division steeper in grade. Then the next heaviest engine (Mogul) can just haul the forty loads of 20 tons each. On the third heaviest division, the third engine in weight (Consolidation) is just sufficient. Finally, on the steepest mountain division, the special (Mountain) engine of the company is required. A line should not be located regardless of any provision for hauling the usual train over it. Locate a road to operate it. If an American engine which you have be too weak, use your gradient which the Mogul can economically haul over. It is folly to have so many different rates of main gradient. If a country is not generally 1.25% country, try to lengthen the line a little; do a little more grading at difficult points and get a 1.00% line. In any case, make it one thing or the other, and never introduce, say, 1.15% as a new maximum rate. Locating engineers leave many unnecessary problems for motive power men.

Under the very best conditions we lose by increasing the rate of maximum grade, the exact difference in demand upon the locomotive caused by that gradient. We may lose more. As a rule,

there is greater difficulty in operating the high grade division without more incidental losses.

Having computed the resistance due to the two maximum gradients we may capitalize each or convert each into distance to be added to measured length to equate for maximum gradients. The former is the better plan. As we have said, the conclusions for choice between two rates of maximum grade seldom need to be taken into account with details of line.

MAXIMUM CURVATURE.

We next consider curvature in the general case for changes of route which are not minor ones. Curvature like gradient is of two kinds, limiting (or maximum curvature) and minor curvature. Limiting curvature like maximum gradient has two distinct functions, one limits directly and immediately the value of the line and the other simply increases operating expenses. By a limiting curve we mean a curve so sharp that its resistance to traffic is the greatest of the obstacles on that operating division. It has all the effect of the one maximum gradient on the division. Limiting curvature is exactly like maximum gradient and need not be considered at length here. Practically, the curves rarely limit the train length or weight. A sharp curve not infrequently causes trains to "slow up" for safety. That fact effects virtual profile and should be taken into account precisely as a "stop"—only less in degree.

For minor curves (and all curves are minor save in the extraordinary cases just cited) we can compute the resistance, as heretofore shown for minor changes, at ½ lb. per ton per degree of curve. We must not forget that we are comparing preliminaries. If the lines are located and the curves equated for on the profile, we need not consider them. They are already equated into gradient. Or, if on the preliminary profile vertical offsets are made at curves to allow for such equating mentioned, we need not consider curvature.

FINAL CONSIDERATION.

We have said that generally, it is best to compute the capitalized value of the line for at least each class of trains. Where fast time must be made by some of the passenger trains, the velocity resistance may be taken into account. We have seen that this resistance is not well known. For the velocity resistance for an entire train we must use Goss's table (Chap. VII.). It probably gives a result none too large. The table gives the lbs. of tractive power. Dividing by 7 lbs., we have the number of tons of train which gives equivalent resistance at ordinary speeds on straight, level track. On certain long maximum gradients it will be found that no engine can maintain all of the desired speed. The comparison will at least throw a side light on choice of routes. Ordinarily, it is the freight and not the passenger trains which must be first considered.

Starting resistances are very important at some localities. They prohibit some trains stopping at some stations. We have seen (Chap. VII.) that for the first 700 ft. the starting resistances added 0.70% to the grade against the traffic and for the next 1,400 ft. added 0.25% to that gradient. When grades at stops are not almost level these starting gradients are apt to convert the profile grade at the stop to a maximum grade, or even beyond that rate of grade.

It will be noticed that we have disregarded some matters of no little importance. We have not spoken of the fact that rails on ruling gradients wear out faster, nor of the fact that rails on curves do not last so long, while ties are more apt to be made useless through double spiking, back spiking or respiking. Track men usually consider that cuts are more expensive to maintain than fills. Some say they cost 50% more to maintain. This is truer in the first few years after construction, while slopes are filling side ditches after each heavy rain. Later, banks settle and grow narrow through erosion of slopes and finally cause a large cost to take out the sag which comes on every large fill and to widen the roadway so that ballast or even ties will stay on the embankment. But the larger questions are most prolific of serious problems, and it is upon them that the engineer must concentrate his attention.

CHAPTER VIII.

Records and Cost of Surveys.

A record may be for temporary use or for permanent filing. Field work, of which notes are not kept, is of no value to the company which pays for it, save through the medium of the employee who did the work. To that employee the field work, of whatever sort, is of passing value unless he takes sufficient notes. The mind cannot retain impressions and facts very long, especially when occupied with other and urgent matters. Men can carry the full details of 100 miles of location in their heads *at the time.* Later, and when other important work has intervened, the memory grows dim about that 100 miles, although glancing at a profile recalls much of it—in a flood of recollections. No matter if it be even a short reconnaissance in very easy country *always take notes,* even though you have had long experience and are following up that reconnaissance at once yourself, with preliminary and located lines. An engineer who depends altogether, or even primarily, on his memory is an unsafe man; he will have to back up with the party much through errors of reconnaissance, and his cost of work per mile will be high. This fault of too few, or no, notes is more common among older engineers, or those whose earlier education has not given familiarity with the pocket instruments or facility in sketching and recording.

There is an opposite evil, viz., taking too many notes. This is a clear waste of time and money, and a plain indication that the work is not understood. Not knowing what notes are needed one may try to take everything in sight, fearing that something left out might be needed in the future. This is the fault most common to students just beginning work, to engineers of the Government surveys now beginning railroad work, and to those engineers who consider railroad surveying an end and not a means. We must remember that we are surveying for a *railroad* and not for a topographic *map* of the country. If facts needed by the railroad company in the prosecution of its enterprise are not recorded, the work is crippled, or even misguided. On the other hand, if facts the company does not need are recorded, its time and its money are thereby lost by the lack of judgment of its engineers. The best levelmen, transitmen, topographers, reconnaissance men, are never able to tell what notes are needed or are unnecessary unless they are railroad engineers or are instructed by such engineers. It is a practical plan for the chief of party to instruct each man what things he must see and report or note down, arranging that to each of two men be assigned the essential details of the alinement, profile, bridging and classi-

fication. This enables one man to check the other, and at the worst usually gives one record. It is practically impossible for both to omit the note. Then let the chief of party himself closely watch and check the assistant (or topographer) for that amount of details and general information which must go to round out a map and profile.

CHARACTER OF RECORDS AND NOTES.

In general records must fulfill three requirements, viz., they must be intelligible, consecutive and complete. By intelligible is meant readily understood by one competent to understand or by one who could reasonably be expected to make use of them. The records of a reconnaissance should be intelligible to the chief engineer or to any chief of party. They do not need to be understood by the land agent or the attorney. On the contrary, the records of a located line are not intelligible unless a land agent or an attorney of the railroad company can readily understand and obtain information from them.

Records must be consecutive. They must start on a definite date, by a certain person from a definite point, fully described in detail, and any connection with another line or level datum must be plainly stated. The course of old surveys often lacks in initial. Leaving the initial point in a certain way there must be no slip or gap in the notes until the destination or end of the route is reached. Scrappy notes are most deplorable. They cannot be platted on paper. They cannot be followed in the field. A strain of German thoroughness is here needed by all locating engineers.

Records must be complete. This does not mean that all obtainable information must be secured, but that it is complete for the purpose for which the records are intended. Nothing must be neglected in one place, and attended to at every other point on the survey. Leave nothing behind you which some one else must go back for. Go and get it yourself before you sign the notes. If a man of the party gets negligent send him back on foot a few times. If he still neglects change the duty to a better man. Remember *not some things* but *everything*, and leave no dropped stitches. Make the company feel that when you send in notes—that ends the survey, and all information necessary is on file.

The writer wishes here to make a distinction in which not all engineers may concur. Notes are strictly professional papers, while records are not. *Notes* on railroad location work are for the man who made them, or for such engineers as in the organization of the company need to use the notes. Notes are technical papers or outlined drawings, and may consistently contain every conventional sign, every abbreviation and every device generally understood by railroad engineers. This is to save time and money. *Records,* unlike notes, are for the laity to use in a general sense, and for those engineers not strictly railroad men. Records must have no professional provincialisms, but be readily understood by engineers at large, or by any official of the company whose duties bring him in

contact with maps, profiles and records. This distinction will help us in keeping notes and in making records.

Set down what is needed by all who will use it and in the briefest form that may be comprehended. You thus do all that is required without waste of time or cumbering note books. It is evident that an experienced assistant can take better notes in less time than one who is only a topographer; because the former knows better what is wanted and where to stop.

USES OF MAPS AND RECORDS.

It may be generally said that there are three quite distinct uses for maps and records: (1) To guide future work. This embraces all reconnaissance notes and generally all records of preliminary work. (2) To estimate cost of construction, make bills of material, let contracts for construction and to enable at once steps to be taken for securing right of way, filing maps and profiles required by law and instituting condemnation proceedings for right of way. In other words, on the receipt at the chief engineer's office of the records of a located line through a country he has all the information necessary to buy material, let contracts, and buy or condemn right of way. The chief engineer can estimate the cost of construction and date of completion of all or any part of the work. These are location records. Some preliminary lines, if very close, fulfill to some extent a part of these requirements. (3) To preserve the line in the archives of the company for reference. This fully describes and records the initial history of the road. Omissions are dangerous, for such records must give legal proofs hereafter. This is the land line record, the topographic map, the construction record, and must show or be accompanied by quantities, classification, kind and location of structures, etc. It is made from location and construction records. A location record may be in pencil, or be a tracing. The record of this third class should be on paper, in ink, with full titles of the exact corporate name, dates, etc. It is a "Finished" map and profile and accompanied by the "Original" notes. All other records lead up to this. Having this record all other records for that work on that line and at that place are of small value.

RECONNAISSANCE RECORDS.

Reconnaissance records are of two kinds: (1) That report of a reconnaissance for route which considers what local traffic may be had and what obstacles to through traffic a region offers. (2) The field notes of a reconnaissance for line made by a chief of party or a locating engineer as a basis for a preliminary line. The reconnaissance for route may be called the grand strategy of railroad location, while the reconnaissance for line is the tactics. The first is usually made as a written report and shows the industries and product of the country tributary to the proposed line with the class, volume and direction of the business. To judge the volume and

kind of business a country will give is a complex science. It requires traffic knowledge and broad acquaintance with country. This report must show also distances, directions and grades of the proposed line. This is less difficult and pocket instruments well used and checking an eye for country should give reasonable results. A report of this general kind herein described may well be a professional paper of a high grade to which a most capable and experienced railroad man has given his best efforts.

The reconnaissance for line is naturally subsequent to the report just described, and is made by a chief of party to find where a preliminary line should be run in one part of the route. This reconnaissance may extend the entire length of the line and should extend not less than fifty miles on a long line. The equipment and instruments have been already described.

PRELIMINARY SURVEY RECORDS.

Records of preliminary survey should be for immediate use by the field party which makes them. For when practicable to do so it is cheapest and best to run the preliminary necessary for, say, ten miles and then locate the line before moving camp, or before proceeding farther with the preliminary, if no camp be used. When this plan is followed the preliminary records may with fair safety be destroyed. To do so is now the custom with some good railroad companies. If records are to be destroyed they need not be as consecutive or as full in the historical notes. Records must perform the function required of them—they must give light on the location of the line which the preliminary line running brought out.

Note books of preliminary surveys must give full data for their map and profile, and contain all possible information for retracing that preliminary line in the future. They must form a basis for a good approximate estimate of grading quantities with reasonable classification of materials, and give sufficient data to enable an approximate estimate of the bridging on the line. Finally, and of far more importance, the preliminary records, note books, map and profile must show a fair representation of the best located line that route will furnish. Where the preliminary is too far to the right or left the topography notes and the map must state the fact and show that line sketched or dotted in. Where such a line offers there must be shown on the preliminary profile the ground line of that modified line designed to improve the preliminary line. These "dotted in" lines must not claim too much. They must not be used to make amends for poor preliminary work, or to misrepresent the fact by claiming a better line or less cost of construction than can be had. A "dotted in" ground line should only be done by the chief of party while walking over the ground and taking new heights to paced distances out at each point where the slope changes. Such ground lines are records. Guessing may be indulged in on reconnaissance, but it has no place on a preliminary record.

The fact must be kept in view that a preliminary, and therefore its records, must show the best line that route affords. Otherwise capital may be turned from its proper channel. At the same time if by "dotting in" or by poor instrumental work that preliminary is made to show a better promise for a located line than exists, capital may be enticed to that route through falsehood. In practice, where one engineer runs the preliminary and another the located line, the former will usually claim too much by "dotted in" ground lines and alinement.

The form of notes and the general conditions governing notes in preliminary do not materially differ from those for the located line which is next considered. Such instrumental work on location, as running in curves, but not done on preliminary, is not of a nature to require different ruling of the page. The same book may be used for either preliminary or location.

LOCATION RECORDS.

Location records are primarily for construction purposes, and, secondarily, for preserving full knowledge of the line which may be valuable for reference in future. A location record is what the locating engineer leaves behind him for others, who are presumably not locating engineers. Therefore such records must be clearer, with more explanatory matter, than is needed in reconnaissance or preliminary notes and records which are for the use of locating engineers or others versed in such work. As a basis for construction the location records must show the alinement in its every element. It is not enough to give the P. C. degree and direction of curves and the P. I. The elements of the curve must be shown just as computed for running in. The P. I. (point of intersection), the Tangent Length, the Total Angle and the Length of Curve must all be shown. In grades as well as alinement the information must be full. There must be every aid offered to the construction engineer in retracing the line and levels. In the office of the chief engineer the location records, by mere inspection and with no man in that office who ever saw the line or who ever saw any man who had seen the line, must give the quantity and quality of each kind of work needed to build that line. Not only must the record notes show the heights for computation of grading quantities, but the classification of that grading as well. Not only must the profile show a wooden bridge, but whether a pile or trestle; if a pile bridge, how deep the penetration; if a trestle bridge, whether it rests on mud sills or on foundation piles, and of what length; if a span bridge, the length of span and character and depth of foundation. It must also show where small drainages must be ditched and where culverts and other small openings are needed in kind and size; where cattle guards and road crossings are needed. The records submitted must enable the chief engineer to determine the kinds and amounts of material and let all contracts. It must also

enable him to advise the president of the road the length of time needed for construction.

Land lines and right of way are very important matters of location records. The map must show section, township, range, county and State lines, with the numbers and full designation of same. Names of owners should be shown as correctly as possible. Angles of land lines to the tangent of the center line must be taken at least once in each township and the distance from one land line crossing to a section corner measured once in each township. Of course the station and plus must be shown at each land line crossing. In short, the location records must give all facts pertaining to land necessary to be known in order to take steps to condemn the right of way. This will vary in different States. The company should be able at once to enter into that legal period which the law says must elapse between the time the company takes steps to secure the right of way and the time the right of way may be entered upon by the company to begin work. Many delays for right of way are chargeable to insufficient land line data secured through location records.

Only in one sense can it be said that the preservation of knowledge of the line is the secondary object of location records. It is secondary because the requirements for construction are first in priority of date of use. It is also true that all knowledge gained for construction is of use as a permanent record. The maintenance is most economically based on construction. Land damage is best based on original surveys, and right of way maps have a value which the lapse of time enhances. The location of buildings and of side tracks must be added to the location records at the time of their construction. But to make a survey or remeasurement of a line of road just after completion should never be necessary if the location records are all they should be. The plusses to "head blocks" from original stations are readily found, and the plus and amount and direction of the offset to buildings are all readily obtainable by the construction engineer. The "head block" plusses should be checked by measurement of length of siding. The plusses to bridges should be taken by the bridge engineer during construction. They will vary a foot or so from the bridge location, as given by the grading engineer. On the location profile, in the office of the chief engineer, is the final place for record of such supplementary notes. "End of Track" at each day should be placed there. The final estimate for each section should be placed on this profile. It is valuable in case estimate sheets are lost in future.

FORM OF NOTES.

The form followed in keeping notes is usually the first point considered. It is here placed last, for the *form* is less important than the *matter*. Facts are essential. The form in which they are recorded is a convenience, not a necessity. It is the right hand page, and not the left hand page, with its columns, that shows whether the levelman has kept notes well. Any levelman can keep the columns

on the left hand page, but it requires a railroad levelman to keep the side notes on the right hand page fully, briefly and well. Many established companies have private instructions for each instrument man, showing how notes shall be kept for uniformity in that company's work. The form of note book, transit and level, with the exact width of page, rulings and headings, are here shown, as used by the Mo. Pac. Ry. These pages are 7¼ in. long. This company uses a transit book or a level book of the same form, whether it be preliminary or location. The Mo. Pac. uses the same book for topography as for transit notes.

NOTE BOOKS.

Originally the transitman kept the topography, then the transit was run by an assistant transitman, who kept no notes. The A., T. & S. F. Co. uses a large page book for topography—of course ruled in squares to save scaling. Companies differ as to what is convenient. The reasons for thinking that the rulings and headings used by the Mo. Pac. Ry. are convenient is that the B. S. and the F. S. on turning points, stand in separate columns and not with F. S. on points for the profile, marked Int'e on notes, thus enabling the levelman to add the front and back sights readily. This was the rule in that company's earlier work, and the rodman was not depended on for checking. Rodmen, however, should be competent to check the levelman on turning points and height of instrument elevation. Both these checks are necessary. The Santa Fé form of level book keeps elevations of turning points distinct from other elevations and enables the levelman more readily to add the + sight to the elevation of the turning point to get the Ht. of Inst. The + and — nomenclature is better in designating sights than the B. S. and F. S. systems. The form of the transit notes is of less consequence than the form of the level notes, for the levelman has the most field computing to do, and it is important that the form of notes aid these computations. The right hand pages of the Mo. Pac. Ry. transit book are used for topography—the topography book being exactly like the transit book. The center line of the page is considered to be the transit line, and the stations run up the page. No mark should be placed by field men on the outsides of field books, except when the printing of the stationer misleads. The outside is reserved for the standard marking of the chief engineer's office. But in the front of each note book and on the first ruled page must be carefully stated all information needed to identify the notes in an office.

The date of beginning and of ending the notes in this book must be stated on the first page. The corporate name as well as the system name of the company for that line should be given. In this first page of each level notes should also be put the name of the rodman as well as of the levelman. On the first page of each transit book *must* be put the name and rank of each man of the party without exception. All these notes on the first page are in ink.

Station	Al't	Needle	Angle	Comp'd Course	
1		N45°45'E		N45°44'E	
850 △					
9					
8					
7					
6					
5					
4					
3					
2					
1					
840					
+94.9 △	PI				
9					
8					
+07.6 △	P. I.	N45°45'E	5°45'		
7					
6					
5					
+19.9 △	P.C 1°R				
4					
3					
832		N40°E		N39°58'E	

Left-hand Page of Transit Note Book, Mo. Pac. Ry.

31

4/7 '02
J. A. Roberts

Bright Sun
Sighting fair - Some Haze
No Wind

Deflect's — C. at 847
9+94.8 = 2°52'
9 = 2°24'
8 = 1°54'

Curve at 847
I = 5°45'
T = 287.7
l = 575.0
P.C = 4+19.9
P.T = 9+94.9

7 = 1°24'
6 = 0°54'
5 = 0°24'
4+19.8 = 0°0'

Right-hand Page of Transit Note Book, Mo. Pac. Ry.

Sta	B.S.	H.I	F.S.	Rod	Elevation		
800		1308.27		3.2	1305	1	
1				1.7	6	6	
⊼	1.96	09.08	1.15		1307	12	
2				1.3	7	8	
3				1.04	8	04	
4				1.6	7	5	
5				3.4	5	7	
6				4.2	4	9	
7				5.5	3	6	
8				6.4	2	7	
⊼	5.51	1307.54	7.05		1302	03	
9				5.3	2	2	
+25				6.0	1	5	
+50				2.5	5	0	
+65				2.5	5	0	
+90				5.3	2	2	
810				5.4	2	1	
B.m			4.93		1302	61	
1				6.0	01	5	
2				6.0	01	5	
3				5.7	01	8	
4				5.2	07	3	

Left-hand Page of Level Note Book, Mo. Pac. Ry.

49.

10/17 '87

W. G. Warfield }
J. H. Harris }

Remarks

Prairie

1+40 Enter Tilled land

Reading taken on Transit Hub

Cultivated Land

Sand Rock outcrop 125' Lt of Sta 8

+00 Enter Timber

Top of Bank

Water Surface } Willow Creek

" " } H.W. El = 1311.0

Top of Bank 30' Cl. Opg. bet. Slopes

On tack of B.M. in root of Walnut Tree 10"

diam 75' Rt of Center line at Sta.

810+25

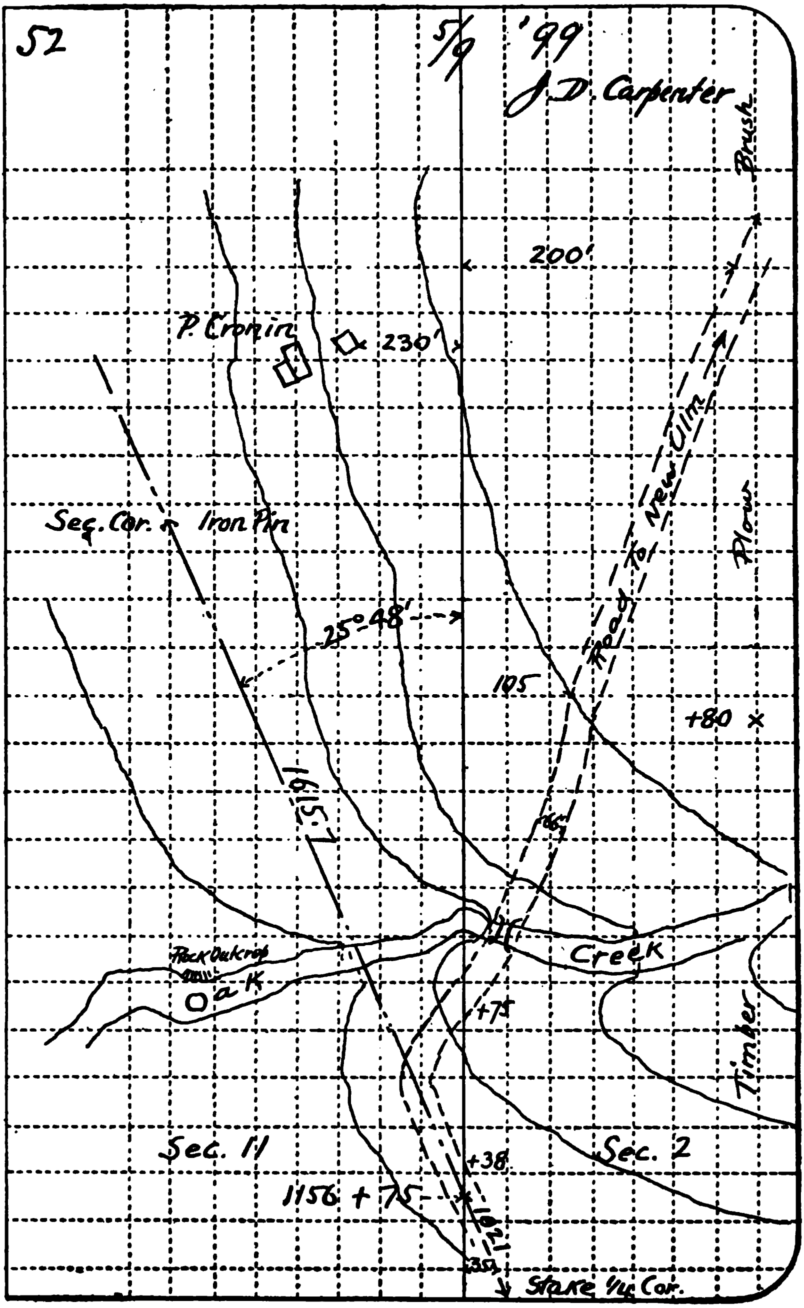
Heavy Timber

Loam

Right-hand Page of Level Note Book, Mo. Pac. Ry.

Station					
1167					
+35.8	=P.C	3°Rt			
6			S.R. 8' below surf.		
5			Farm X ing		
4					
3					
2					
1					
1160					
			P.Br. 30' Cl. Opg.		
9					
8			Divert Road		
7					
1156					

Left-hand Page of Topography Note Book, Mo. Pac. Ry.



Right-hand Page of Topography Note Book, Mo. Pac. Ry.

Each book must be paged. Each day's work must be dated and the beginning and end of each day's work marked. If the book contains more than one continuous line the note book must be indexed on its last ruled page.

It is customary to copy the transit, level, grade, bridge, clearing and classification notes in a book for a certain section. Then make a pencil copy of the profile and a tracing of the map, exclusive of contours, of the same section, and send it to the office of the chief engineer. This keeps that office "posted," enables estimates to be made, and also insures against grievous loss through fire or flood of the sole copy of the notes in the camp. On the Mo. Pac. Ry. these notes as above were sent in promptly at the end of each ten miles of located line.

SCALE OF PROFILE AND MAPS.

The scale of maps and profile varies directly as the difficulties of the work, and it also varies with the different railroad companies. A brief general statement of the matter is all that can be attempted.

Profiles in this country are platted from left to right.[1] It is true almost without exception that but two "plates" are used. These are continuous rolls about 20 in. wide and are cut to one-half, one-third or one-quarter width for use.

Plate "A" is printed 30 horizontal and 4 vertical lines to an inch. Plate "B" is printed 20 horizontal and 4 vertical lines to an inch. One vertical line for each 100 ft. of line (each station) is the general custom, and this practice holds true whichever plate is used. Therefore, it may be said that 1 to 4,800 (1 in. = 400 ft.) is the horizontal scale for all profiles of railroads in practice in the United States. The older roads began using plate "A" profile paper (1 in. = 30 ft.) and platting one horizontal line as one foot. It makes a compact profile. In average country this scale is all that is desired. But for close work in easy country or rock work the grade line cannot be laid closely enough to suit the ground and the right distance from the ground without error. Today, for profiles, Plate "B" is generally used. It gives 20 ft. to 1 in. vertically instead of the 30 ft. to 1 in. of Plate "A," and this change is very desirable. It is best at the start to accustom one's self to this scale. For preliminary lines in difficult country or for close grade line laying in any country neither of these scales is large enough. The So. Pac. Co. use five times the scale of Plate "A," i. e., each vertical inch represents 6 ft. instead of 30 ft., the horizontal scale remaining the same. This, or something similar, is imperative in difficult places.

For maps there are two classes of scales. (1) For working plans and (2) for plans for records. The maps are platted from left to right, the top being north. Some plans for records are 1 to

[1]Following the custom of the surveys in 1872, the Texas & Pacific Ry. profiles were platted from right to left so the top would be to the north on that road. The maps were platted from left to right. It was most awkward.

24,000 (1 in. = 2,000 ft.). These will serve for filing in county record office, but are fit for little else. The writer used this scale for some time under instructions in Texas, and whenever the country became at all difficult the map was useless. So much of the line had to be replatted to larger scale that time and money were really lost. It is too small a scale for any practical use or real economy. This scale was changed in later work to 1 to 12,000 (1 in. = 1,000 ft.). For easy country this scale will do very well. In the writer's experience no smaller scale should be used. It will be found, of course, to be too small for difficult country or for any place where a choice between preliminaries must be made. The next larger scale used by the writer was 1 to 4,800 (1 in. = 400 ft.). This is the same as the horizontal scale of the profile, and is therefore convenient for comparison. It is to be commended for preliminary work in moderate country or for a location map for right of way use in purchasing lands. Some engineers use a scale of 1 to 2,400 (1 in. = 200 ft.) when the scale last mentioned proves too small. This is of doubtful utility, for it is too small a scale for difficult country. A scale of 1 to 1,200 (1 in. = 100 ft.) is none too large where great difficulties are to be met. The writer uses three scales: 1 to 12,000 (1 in. = 1,000 ft.) for easy country and for filing where any scale will do; 1 to 4,800 (1 in. = 400 ft.) for preliminary maps in easy country, and 1 to 1,200 (1 in. = 100 ft.) for the preliminary maps in difficult country. These will serve for general rules in the selection of scales for maps and profiles. Engineers differ widely in their practice in this regard. The scale must be large enough to serve fully the uses of the plat. When it is to a still larger scale the plat is a hindrance through its useless size. The former practice was to plat maps on a continuous roll of paper. Except in very straight lines this plan is not suited to field platting on a limited drawing table; sheets are better. Manila paper is used in the field, and it is practically impossible to keep clean preliminary maps so as to ink them in for records. The length of the sheet must not exceed that of the table, and in difficult country it must not be shorter. Sheets vary from, say, 18 × 24 in., 18 × 36 in., to 24 × 48 in. The size of the field drawing table should be considered as much as the character of the alinement.

COST OF SURVEYS.

It may be said, probably without fear of controversy, that for many years it has been generally considered that $100 fairly represents the cost of locating one mile of railroad in the United States. This includes the reconnaissance and preliminaries for that mile. This estimate has the force of years, the advantage to the memory of being a round figure, and the merit of being above rather than below the average cost per mile. Estimates should always err, if at all, on that side of safety. One of the most experienced locating engineers of this country gives it as his opinion that "as an average, location, complete, costs in easy prairie country $50 per mile.

and in timber country $150 per mile." All of these prices are for all reconnaissance, preliminary and located lines per mile of adopted, located line. This is the proper unit of cost and not the actual miles of line run. The above costs for location may be taken as averages, under the conditions stated for usual lines. To pretend to give any estimate for unusual cases is of no service, though of interest. Pack train work or the use of packers is a matter entirely outside the above average cost.

The Details of Cost of Location together with the Character of Five Lines of the Mo. Pac. Ry. are here Given.

	Ottawa, Kansas, to Council Grove, Kansas.	Nevada & Minden Ry. from Minden to Chetopa.	Stockton, Kans., west through Hoxie, Kansas.	Burr Oak, Kansas, to South Center, Kansas.	Concordia, Kansas, to Salina, Kansas.
	1886	1886	1887	1887	1887
Dates beginning and ending work	3-12 to 5-26	1-1 to 3-12	1-22 to 3-13 4-6 to 5-26½	3-14 to 4-5½	5-27 to 7-8
Total days engaged	78	70	103½	22½	35½
Total week days	68	60	92½	19½	30½
Length of located line, miles	75.73[4]	69.52[1]	83.62	31.17	52.20
Average miles located line per day	0.97	0.99	0.805	1.39	1.47
Average miles located line per week day	1.11	1.12	0.904	1.60	1.71
Total cost of location	$3,395.60	$2,971.12	$4,802.96	$940.43	$1,609.86
Average cost of location per mile	44.83	42.74	57.43[2]	30.17	31.80
Cost of party per day	43.53	42.44	46.40	41.80	46.77
Cost of party per week day	49.93	49.52	51.92	48.22	54.42
Degree of max. curvature	6	3.30	3	5	5
Average no. deg. per mile	23.37		30.20	40.41	19.03
Max. gradient	1.25[5]%	0.80 to 1.%	0.8%	1.25%	1.25%
Av. per cent. length max. gradient per mile	39%	22%	30%	31%	21%
Av. no. lin. ft. bridging per mile	126.4	118.5	110.8	88.0	88.8
Av. cu. yds. grading per mile	19,185	......	......	19,636	13,000

[1]Includes a preliminary to Oswego, rated at 3-8 location cost.
[2]Includes cost due to delay through Legal Department.
[3]Includes delay of four days by K. of L. strike.
[4]Includes R. of W. party to M. K. & T. construction at 3-8 of location cost.
[5]On the west end a 1.50% gradient was laid on the profile as located, to expedite construction.

A few individual cases may add something, however, to the general fund of information. The writer knew of a case in Central Kansas where an old chief of party contracted to run the necessary preliminaries and locate in very easy country at $25 per mile of

located line. Money was lost on the contract. The actual cost of the location complete, by a good man, for the C., M. & St. P. Ry. in the woods in Wisconsin, was $142.80 per mile of located line. This was considered good work. On the plains of Texas, but where there was some pretty heavy work, the complete location cost about $65 per mile. Farther away from supplies, with water scarce, and subject to accident, the cost exceeded the amount just stated. In the "Panhandle" of Texas the writer's party reduced the cost to $60 per mile as an average. That party cost $50 per day ($32.30 for salaries and $17.70 for subsistence). According to the notes kept by the assistant (the late W. J. McNulty, C. E., of Fresno, California), for a few months the average cost per mile of preliminary line run was $27, while the cost per mile of line while actually at work (bad weather and delays excluded) was $18. On this line the average cost of grading was $2,200 and the bridging $50 per mile.[1]

The work was done by the writer and these notes were made by him at the time. They were kept to study what progress was being made in reduction of cost of location per mile of located line, the difficulties considered. That locating party was told, at the end of each line, what the cost per mile of located line was for that survey. Each time they were "going against the record." That these results are below the average for the United States rises primarily from the fact that the party was an old organization, picked from many location and construction parties. At the close of the survey of the fifth line here shown each man of the party had been with it and in his present position for at least 900 miles of line run. Of course they had become expert, for the chief of party never "let up" in discipline. The level rodman and cook, in their respective capacities, had been with the party for some 1,200 miles of line and the head chainman for 1,300 miles.

For the three last lines a distribution of accounts is shown.

Salaries	$4,452.19
Subsistence of men	1,285.16
Team hire	513.25
Expenses (traveling and incidental)	332.72
Fodder for stock	223.15
Outfitting, renewals and repairs	217.35
Fuel	142.87
Medicine	44.10
Sundries (including lumber for stakes)	182.75
Error to balance	9.71
Total	$7,403.25

Distribution of total cost account for the last three lines, viz., $4,802.96 + $940.43 + $1,659.86 = $7,403.25.

[1]So stated by F. E. Bissell, C. E., Chief Engineer for the construction of the line in 1887-8.

It is instructive to note that the salaries are 60% of the total cost, while subsistence is but 17½%. This admonishes the wise chief of party to feed liberally if he would lower the cost per unit of survey.

The quarters and the food and its preparation are never beneath the notice of a chief of party but merit his early and ceaseless care. Feed men well, treat men well, and if the cost per mile of located line is not low then errors were made in selecting men. Driving men will not compete in cost with leading men, provided the men are of the right kind.

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